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LONGWALL MINING
IN
WESTERN CANADA

HANDBOOK

A Two Day Seminar Sponsored by CANMET and Presented by
the Faculty of Continuing Education

THE
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OF CALGARY

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November 14 and 15, 1983

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321 pp

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TWO DAY SEMINAR 14/15 NOV 1983

Introduction

This seminar has been arranged under the Technology Transfer Program of CANMET (Department of Energy, Mines and Resources, Canada). It follows the completion of a planning and engineering project carried out by McIntyre Mines Ltd., of Calgary, Alberta for CANMET, entitled "Longwall Demonstration in Western Canadian Coals: Phase 1 - Mine Planning and Systems Engineering".

The purpose of the seminar is to make available to the Western Canadian coal mining industry information on longwall mining relevant to its needs and to create a forum for discussion of the concept of joint industry/Government mining demonstration projects.

The seminar has been organized by John P.L. Bacharach & Associates Ltd., Consulting Mining Engineers, of Calgary, Alberta and the Faculty of Continuing Education of the University of Calgary.

LONGWALL MINING IN WESTERN CANADA

TWO DAY SEMINAR 14/15 NOV 1983

TABLE OF CONTENTS

1. Executive Summary

    1.1 English
    1.2 French

2. Program Outline

3. List of Participants

4. List of Speakers

5. Opening Address - G. Zahary

6. The Resource Recovery Perspective - D. Henderson

7. Safety - H. Sahay

8. Production & Productivity - I. Muirhead

9. Geological & Geotechnical Considerations for Longwall Mining - G. Jordan

10. Mine Design - J. Greenwell

11. Equipment - H. Owen

12. Case Study - Smoky River Demonstration Longwall - T. Robson

13. Special Longwall Applications - J. Bacharach

14. Case Study - Snowmass Demonstration Longwall - J. Reynolds

15. Notepaper

LONGWALL MINING IN WESTERN CANADA

TWO DAY SEMINAR 14/15 NOV 1983

EXECUTIVE SUMMARY

(English)

Opening Address

Participants are welcomed to the seminar and how it came to be is described. Participation by those attending is encouraged.

The high cost of a longwall system is brought out and a "pooling of resources" is suggested to demonstrate reliable production capacity of the system.

The seminar is presented by the University of Calgary and sponsored by CANMET. Funding was provided by START (Short Term Assistance in Research and Technology) - a program funded by EMR to help industry directly in solving short term problems in production and productivity.

The Resource Recovery Perspective

Longwall mining can improve resource recovery by upgrading areas of coal unmineable by other technology into the mineable category and by improving the percentage of mineable coal recovered. Longwall is compared with the two principal mining systems currently employed in western Canadian underground coal mines - room and pillar and hydraulic.

The parameters influencing the mining system and recovery include seam thickness, gradient, depth of cover and structural geology.

Ratings are given for the effectiveness of resource recovery in relation to seam thickness for the three mining systems under consideration. Hydraulic mining has the highest ranking (1), longwall (2) and room and pillar (3). The longwall ranking could be substantially improved by the application of multi-lift or secondary caving systems.

In terms of gradient, the ranking is longwall (1), hydraulic (2) and room and pillar (3). Rankings on the basis of recovery potential according to depth of cover are longwall (1), hydraulic (2) and room and pillar (3). Structural geology considerations result in the ranking: room and pillar (1), hydraulic (2) and longwall (3).

Within a mining panel, longwall provides the highest recovery. However, when considering the overall mine layout the need for inter-panel and main road pillars mitigates against high resource recovery.

Longwall is less flexible than room and pillar in respect of protection pillars for oil and gas wells, but its controlled subsidence profile improves the opportunities for mining under surface features sensitive to disturbance.

Although the improvement may only be marginal in western Canadian conditions, longwall mining can improve resource recovery.

Safety Aspect

Studies of the longwall system in the USA indicate a significant reduction in injuries compared with room and pillar mining, which is currently the most widely adopted mining method in western Canada. Statistics from the UK show a continuing improving trend in accident reduction as mechanised longwall mining accounts for an increasing proportion of total production. This reduction in accidents has been accomplished with an increase in productivity.

Factors leading to improved safety include both better equipment and engineered mining systems. Statistics cited from a survey carried out in the USA through 1978/1979 show a reduction of 40% in total disability accidents for longwall, compared with continuous miner operations. However, although disabling injuries from electrical causes and roof falls show a marked decrease, machinery and material related accidents increased. These types of accidents could, however, be reduced by improved training. UK experience indicates that retreating longwalls suffer less falls of ground accidents than advancing longwalls.

Pneumoconiosis statistics cited from the UK show a marked reduction in new cases between 1958 and 1979. US statistics show that respirable dust is generally under control and average concentrations range between 2.3 and 3.6 mg/m3.

Longwall mining merits serous consideration as a safer method of mining coal in western Canadian underground mines.

Production and Productivity

A brief introduction to alternative underground coal mining systems is provided describing longwall, room and pillar and hydraulic mining. A fuller description of longwall reviews layouts, equipment and operations. The rationale for the adoption and growth of longwall production is provided.

Manpower, production and productivity levels are reviewed and compared with room and pillar and hydraulic mining. Both record and typical performances are compared and the conclusion is drawn that, in general, longwall can achieve five times the daily output of a continuous miner though both systems are very sensitive to seam heights. Typical capital and operating costs for the three alternative mining methods are discussed.

The conclusion is drawn that longwall offers considerable advantages over room and pillar, particularly in the areas of production, productivity, manpower levels and operating costs. Hydraulic mining above drainage is attractive, but because of its limited usage it is difficult to make a general comparison with longwall.

Experience and facts prove that in the right circumstances and conditions, longwall is safer, more resource efficient, more productive and cost efficient than room and pillar.

Geologic and Geotechnical Considerations for Longwall Mining

Geological and geotechnical interpretations are processes of prediction based on data from specific locations. Their quality is based on the collection of accurate data, and the selection of relevant models. Longwall mining often requires high capital investment and is particularly sensitive to variations of geology, so great accuracy is required in geologic interpretation. Longwall mining studies such as those by McIntyre Mines should be considered to be the required norm rather than extraordinary in-depth investigations; other mining methods could equally benefit from that level of geological and geotechnical detail. There are many examples where productivity, financial performance and safety have been jeopardized by inadequate initial geologic and geotechnical studies.

Geological factors that effect longwall mining are of two types: sedimentological and structural. Sedimentological factors include correlation, seam descriptions, descriptions of roof and floor strata, and depositional models. Structural factors include descriptions of observed structures such as those normally presented on cross-sections and structure contour maps, and structural analysis documenting characteristics such as joints, cleats and other small-scale features. It is essential that the geologist convey the signficance of those factors to the mining engineer; hazard analysis can provide a semiquantitative expression of the net impact of the geological factors.

Geotechnical factors that affect longwall mining include material strengths, state of stress, hydrology, and methane content. The study of these factors affects the specific design of roof supports, specifications for the dimensions of the longwall face and pillars, ventilation requirements and the control of water.

Mine Design

Longwall mining requires a large initial investment. A satisfactory return depends on high volume single source production. The mine designer must secure this production at minimum risk.

In assessing reserves the basic questions is "will it longwall"? Criteria include caveability, overlying strong beds, geometry, tectonic fractures, gradient and surface features. Before any longwall is contemplated there should be at least eight years reserves of recoverable coal.

A structured "rolling" planning process should be established. The three basic longwall configurations - advance, retreat and hybrid advance/retreat are discussed. In designing the longwall geometry, some compromises are often necessary. The horizon in the seam must be selected to achieve a balance between horizon control, maximum clean coal yield and support effectiveness. In practice, face and panel lengths are selected to maximize the extraction of a given reserve block, within equipment design limits and recognizing any requirements for future extraction in adjacent seams.

Wall and panel alignment generally pre-determines development configurations. Designs should give high priority to promoting the best possible wall conditions, even at the expense of development conditions, since successful wall production generally recoups lost efficiency in development.

Operational and regulatory constraints frequently preclude single-entry development and in North America multi-entry room and pillar developments predominate. Development designs are described and consideration is given to factors including roof conditions, ventilation, logistics and percentage extraction.

All the factors reviewed must be considered by the mine designer in seeking to achieve his aim of controlled coal recovery by longwall, within the constraints imposed by the nature of the reserves.

Equipment

The concept of a longwall as a coal producing unit within an overall mine is described and the need to ensure that the longwall is fully integrated into the total mine system is identified and the extent of the integration necessary will be outlined.

Longwall mining systems are adaptable to mining conditions but have limited flexibility to overcome unexpected mining difficulties. Several possible longwall mining layouts are illustrated and the advantages and disadvantages of each system outlined.

To ensure satisfactory mining operations, equipment selected for installation on a longwall face, and for supporting services, must be capable of functioning within the contraints imposed by mining conditions and must be compatible.

Based largely on a two entry retreat mining system, the range of equipment available for longwall are identified including roadway/tunnel development, transportation, longwall, electrical and communication and control.

The advantages and limitations of each equipment type or system are described.

Smoky River Demonstration Longwall

As a step towards a possible industry/Government joint demonstration of longwall mining in western Canada, CANMET contracted McIntyre Mines Ltd. to undertake engineering and system design related to their 9G-4 mine, which had been identified as a candidate location.

Longwalling in #4 seam at Smoky River Mines in the early 1970's was beset with problems, principally related to the equipment then available. Severe roof problems resulted in the cessation of longwall activities. Recent advances in longwall equipment have led to a re-evaluation of the potential of longwall and the engineering study suggests that it could be successfully re-introduced at Smoky River. The engineering work can be categorized in three stages: the development of general design considerations, the formulation of design parameters for the reserves in 9G-4 mine and the preparation of a specific design for 9G-4 longwalls.

The geology of the target area is a gently rolling anticline/syncline pair with dips between 4 degrees and 30 degrees. The block contains sufficient reserves in #4 seam, which averages 20 to 22 feet thick, for a five-year mining program. There are additional reserves in adjacent areas. Geotechnical work confirmed coal strengths at various horizons in the seam and identified the position and characteristics of a band of soft coal lying some 12 to 14 feet below the seam roof. Caveability was assessed from boreholes and workings in the same seam in an adjacent mine.

After consideration of alternatives, a longwall retreating layout with two entry developments was selected to maximize the use of current equipment and know-how. Development roadways would be constructed up to the seam roof and support would be by roof bolts.

A longwall face length of 550 feet was recommended in light of caving considerations, equipment capacity, reserve geometry and the possibility of future extraction in the overlying #10 seam.

Before introducing longwall, additional material and ventilation access would be provided. Panels would be aligned along the strike with faces on full dip. The top ten feet of the seam would be mined using a double ended ranging shearer and shield, or chock shield, supports.

Proposals for development, equipping and face transfers are described.

Development performance is projected to be 100 feet per day, in three shifts, at 208 long tons raw per machine shift. Longwall performance is projected at 9.2 shears per day over three shifts, producing 4,370 long tons raw. The development and production from three panels is projected to amount to 3.8 million long tons raw of which 87% comes from the longwalls and 13% from development. On a raw coal basis, productivity over the five-year project is estimated at 16 tons per manshift from development, 53 tons per manshift from the longwall and 25 tons per manshift for all employed at the mine. Management of the project, additional research goals and capital and operating costs are provided. Under the sales price, operating and capital costs assumptions used in the evaluation, the net present value of the project is estimated at $10.2 million.

In view of the potential benefit to the western Canadian coal industry as a whole and technical and financial risks of introducing modern longwall technology, it is recommended that a joint industry/Government demonstration should be implemented.

Special Longwall Applications

A series of site specific examples illustrate the range of conditions in which longwall mining may be applied. The cases described include thick seam mining by single-lift along the strike, by multi-lift and with secondary caving; thin seam extraction; and steep seam mining along the strike and to the rise.

The example of thick seam single-lift mining along the strike addresses Carbon County Coal Company's longwall operation at Hanna, Wyoming. The multi-lift case describes operations at Daw Mill Colliery in the UK NCB's South Midland Area, where the top slice of a thick seam is mined by advancing longwall, and a second, lower lift, by retreating. Extracting a thick seam by longwall and secondary recovery by caving is illustrated by reference to the Blanzy operations of Charbonnage de France in the Midi coalfield.

North River Energy Company's operations in Alabama, USA, show the potential of longwall in thin seam applications.

Steep seam extraction along the strike is illustrated by an example from Warndt Mine in the Saar, West Germany, and steep seam extraction to the rise by reference to experience in the Lorraine coalfield, in France.

The present generation of longwall equipment provides opportunities for longwalling in a range of conditions outside those generally recognized as conventionally amenable to the system.

Snowmass Demonstration Longwall

A successful demonstration longwall on a 30 degree pitching seam at Snowmass Coal's underground coal operations near Carbondale, Colorado is described, which is being carried out in cooperation with the US Department of Energy.

The principal criteria for pitching seam longwall design and operation are examined. Mine planning considerations are described and reference is made to the problems of entry development in pitching seams.

The selection of longwall equipment for the 350 ft face is described in detail. The system consists of a twin 22mm outboard chain armoured conveyor, a double-ended ranging drum shearer with high powered chainless haulage and two-leg shields working on the "troika" system. The method of controlling the conveyor and shields on a wall with a gradient in excess of 30 degrees is described and other operational aspects, safety and training are reviewed.

Performance for a three-month period averaged 719 raw tons per machine shift with a productivity of 65 raw tons per manshift (longwall to surface).

With the equipment now available, pitching seam longwall is not only feasible, but cost competitive. The troika system of roof control has excellent manoeuvrability, good support and low maintenance requirements. The shearer has proven that it has the power to operate effectively on seams pitching at 30 degrees. Snowmass performance suggests that longwalls operating on pitches up to about 45 degrees, would have the same capacity as those operating in flat seams.

LONGWALL MINING IN WESTERN CANADA

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EXECUTIVE SUMMARY

(French)

Discours d'inauguration

On souhaîte la bienvenue aux participants du colloque, et l'on explique l'instauration de ce dernier. On encourage les délégués de participer aux entretiens.

Le coût élevé d'un système de longue taille est souligné, et l'on propose la "mise en commun " des ressources afin de démontrer la fiabilité de la capacité de production de ce système.

Le colloque est présenté par l'université de Calgary et patronné par CANMET . Les fonds pour ce colloque ont été fournis par "START" (Short Term Assistance in Research and Technology- Assistance à court terme pour la recherche et la technologie), un programme dont l'appui financier provient de EMR pour aider l'industrie à règler **ses** problèmes à court terme dans les domaines de la production et de la productivité.

Des considérations géologiques et géotechniques pour le système d'exploitation par longue taille

Les interprêtations géologiques et géotechniques sont des procédés de prédiction qui sont basés sur des données provenant de lieux spécifiques. Leur qualité depend du rassemblement des données précises et de la sélection de modèles appropriés. L'exploitation par longue taille requiert souvent de forts investissements de capital et est souvent sensible aux variations de la géologie, donc l'interprêtation géologique doit être extrêmement précise. Des études d'exploitation par longue taille, telles celles des mines McIntyre, devraient être considérées comme des investigations mandatoires plutôt que des investigations détaillees extraordinaires. Eventuellement, d'autres méthodes minières tireraient profit de ce niveau de détail géologique et géotechnique. On pourrait signaler plusieurs domaines où la productivité, le succès financier et la sécurité auraient été mis en danger par des études préliminaires géologiques et géotechniques insuffisantes.

Les facteurs de géologie qui influent sur l'exploitation par longue taille sont de deux classes: sédimentologiques et structurels. Les facteurs sédimentologiques comprennent la correlation, la description des couches, du toit et du mur, et des modèles stratigraphiques. Les facteurs de structure comprennent des descriptions de structures observées, telles celles qui apparaissent sur des coupes transversales et sur des cartes hypsométriques (en courbe de niveau), ainsi que le calcul des constructions qui note des caractéristiques telles les diaclases, les taquets et d'autres traits à petite échelle. Il est essentiel que la géologie explique l'importance de ces facteurs à l'ingénieur des mines; l'analyse des risques peut fournir une expression semi-quantative de l'impact net des facteurs géologiques.

Les facteurs géotechniques qui affectent l'exploitation par longue taille comprennent la résistance des matériels, l'état de contrainte, l'hydologie et le contenu en méthane. L'étude de ces facteurs affecte la conception des soutènements du toit, les spécifications pour les dimensions du front de la longue taille et les pilliers, les nécessités de ventilation et le contrôle de l'eau.

Perspectives sur la récupération des ressources

L'exploitation par longue taille peut augmenter la récupération des ressources en améliorant les endroits où le charbon n'est pas exploitable par d'autres méthodes technologiques , ce qui les classerait parmi les endroits exploitables tout en augmentant le pourcentage de charbon récupérable. L'exploitation par longue taille se compare avec les deux principaux systèmes d'exploitation utilisés actuellement dans le ouest canadien dans les mines souterraines de charbon, c'est à dire, le système d'exploitation par chambre et pilier et le système hydraulique.

Les paramètres qui influent sur le système d'exploitation et de récupération comprennent: l'épaisseur de la couche, le gradient, la profondeur du mort-terrain et la géologie structurelle.

On évalue l'efficacité de la récupération des ressources par rapport à l'épaisseur de la couche pour les trois systèmes d'exploitation en considération. L'exploitation par le système hydraulique est au premier rang (1), par longue taille (2) et par chambre et pilier (3). La classification de la longue taille pourrait être nettement améliorée par l'application de systèmes à couches multiples ou par foudroyage secondaire.

En ce qui concerne le gradient, l'ordre est le suivant : longue taille (1), système hydraulique (2) et chambre et pilier (3). Les classifications basées sur le potentiel de récupération selon la profondeur d'enfouissement sont: longue taille (1), système hydraulique (2) et chambre et pilier (3).

Quand à l'exploitation par chambre, la longue taille donne la plus grande récupération. Quand on considère cependant le plan général d'une mine, le besoin de piliers entre les chambres et de piliers des voies d'accès principales contrebalance la forte récupération de ressources.

Le système par longue taille est moins flexible que le système par chambre et pilier en ce qui concerne les piliers protecteurs des puits de gaz et de pétrole, mais son profil de subsidence contrôlé augmente les occasions d'exploitation sous des traits de surface sensibles aux dérangements.

Bien que ce ne soit qu'un progrès marginal des conditions de l'ouest canadien, l'exploitation par longue taille peut augmenter la récupération des ressources.

La sécurité

Des études du système d'exploitation par longue taille aux Etats-Unis indiquent qu'il y a une réduction importante dans le nombre d'accidents avec ce système minier par rapport à l'exploitation par chambres et piliers qui est actuellement la méthode la plus répandue dans l'ouest canadien. Des statistiques provenant du Royaume-Uni montrent une tendance qui s'améliore de plus en plus vers une réduction dans le nombre d'accidents au fur et à mesure que l'exploitation par longue taille occupe un rôle croissant dans la production totale. Cette réduction a été accomplie avec une augmentation de productivité.

Les facteurs qui sont responsables de l'amélioration de la sécurité sont: une meilleur équipement et des méthodes d'exploitation planifiées. Les statistiques citées d'un sondage qui a été effectué aux E.-U. dans les annees 1978/79 montrent une réduction de 40% pour les accidents d'incapacité totale quant à l'exploitation par longue taille, ceci comparé aux opérations "continuous miner". Cependant, bien que des blessures incapacitantes provenant de causes électriques et de chutes de toit aient diminué de façon significative, des accidents reliés à la machinerie et au materiel ont augmenté. Les accidents de ce genre pourraient être réduits si l'entraînement était amélioré. L'expérience au Royaume-Uni indique que l'exploitation par longue taille rabattante provoque moins de chutes que l'exploitation par longue taille avançante.

Les statistiques citées au Royaume-Uni pour la pneumoconiose témoignent d'une réduction importante dans de nouveaux cas qui se sont produits entre 1958 et 1979. Les statistiques aux Etats-Unis démontrent que la poussière respirable est généralement contrôlée et les concentrations moyennes sont entre 2.3 et 3.6 mg/m3.

L'exploitation par longue taille mérite une considération estimable en tant que méthode plus sûre pour l'exploitation du charbon dans les mines de l'ouest canadien.

Production et Productivité

On présente une courte introduction au système alternatif d'exploitation souterraine du charbon: il s'agit d'une description de la longue taille, du système de chambre et pilier et du système d'exploitation hydraulique. Une plus ample description du système par longue taille repasse les plans, l'équipement et les opérations.

La main d'oeuvre, le rendement et les niveaux de productivité sont passés en revue et sont comparés à l'exploitation par chambre et pilier et par le système hydraulique. Et la performance record et la performance typique sont comparées et l'on conclut que, en général, l'exploitation par longue taille peut arriver à un rendement qui est 5 fois plus grand que celui du "continuous miner" bien que les deux systèmes sont très sensibles à la hauteur de la couche. On examinera la question des coûts opérationnels et du prix d'installation pour les trois méthodes alternatives d'exploitation.

On conclut que l'exploitation par longue taille offre d'importante avantages quant à l'exploitation par chambre et pilier, surtout dans les domaines du rendement, de la productivité et en ce qui a trait au niveau de main d'oeuvre et des coûts d'opération. L'exploitation par la méthode hydraulique au-dessus du drainage est intéressante, mais à cause de son usage limité, il est difficile d'en faire une comparaison générale avec l'exploitation par longue taille.

Et l'expérience et les faits prouvent que dans de bonnes circonstances et conditions l'exploitation par longue taille est plus sûre, plus efficace au point de vue ressources, plus productive et plus économique que l'exploitation par chambre et pilier.

Avec l'équipement qui est actuellement disponible, le système de la taille à couche inclinée est non seulement faisable mais il est à prix compétitif. Le système "Troika" de contrôle du toit a une excellente manoeuvrabilité, un bon système de soutènement et de modestes exigeances de maintien. La haveuse a pu démontrer qu'elle est capable de fonctionner efficacement sur des couches inclinées à 30° (degrés). Les essais de la compagnie Snowmass témoignent que les longues tailles fonctionnant sur des pentes jusqu'à 45 degrés auraient la même capacité que celles qui fonctionnent sur des couches horizontales .

Conception de la mine

L'exploitation par longue taille requiert un investissement assez considérable. Un rendement satisfaisant dépend du haut volume de la production à source simple. Celui qui est chargé de l'installation de la mine doit assurer cette installation avec le minimum de risque possible.

Quand on considère les réserves, la question principale est: "Cela se fera-t-il par longue taille?" Les critères comprennent : l'aptitude au foudroyage, les couches fortes au-dessus, la géométrie, les fractures tectoniques, la pente et les structures sur la surface. Avant de songer à l'exploitation par longue taille, il faudrait avoir des réserves de charbon récupérable pour huit ans.

Un processus de planification structuré devrait être établi. On examine les trois configurations de base pour l'exploitation par longue taille: avance, rabattage et hybride. Il faudrait accepter certains compromis quant à la conception de la géométrie de longue taille. Il faut choisir l'horizon dans la couche de façon à effectuer une balance entre le contrôle de l'horizon, le rendement maximum de charbon propre, et l'efficacité des soutènements. En pratique, les longueurs du front et des chambres sont sélectionnées afin d'assurer le maximum d'extraction dans un secteur particulier, en tenant compte des limites de la conception de l'équipement et en reconnaissant toute nécessité d'extraction future dans des couches adjacentes.

L'alignement des murs et des chambres détermine géneralement à l'avance les configurations du développement. La planification devrait accorder priorité à la promotion des meilleures conditions possibles de la paroi, même aux dépens des conditions de développement, puisque la production réussie de parois recouvre généralement toute l'efficacité perdue dans le développement.

Des contraintes d'ordre operationnel et regulatoire sont assez fréquentes dans le développement à entrée simple, et en Amérique du nord, les développements à entrée multiple et à pilier prédominent. Les plans du développement sont décrits, et l'on prend en considération les facteurs tels la condition du toit, la ventilation, la logistique et le pourcentage de la récupération.

Tous les facteurs passes en revue seront évalués par celui qui est chargé de l'installation de la mine, en essayant d'atteindre son but: la récupération contrôlée de charbon avec le système de longue taille, ceci selon les contraintes imposées par la nature des réserves.

L'équipement

On parlera du concepte de longue taille comme unité de production houillère dans l'ensemble d'une mine et aussi du besoin d'assurer la pleine intégration de la longue taille dans l'ensemble du système minier. On fera également un compte rendu de l'etendue de l'intégration nécessaire.

Le système d'exploitation par longue taille s'adapte aux conditions minières, mais ces systèmes ont une flexibilité limitée quand il s'agit de vaincre des difficultés inattendues. Plusieurs schémas d'exploitation seront illustrés et les avantages et les dèsavantages de chacun seront exposés.

Afin d'assurer des opérations minières satisfaisantes, l'équipement sélectionné pour l'installation sur un front de taille et pour un service de soutènement doit être capable de fonctionner selon les contraintes minières imposées, et il doit leur être compatible.

Basé en général sur un système d'exploitation rabattant à double voie d'accès, on identifiera la gamme d'équipement disponible à la longue taille, y compris le développement de voies d'accès/tunnels, le transport, la longue taille, l'équipement éléctrique et la communication et le contrôle.

On exposera les avantages et les limitations de chaque type d'équipement ou de système.

Modèle de démonstration: La longue taille de Smokey River

CANMET qui a voulu faire un pas vers une éventuelle démonstration commune entre l'industrie et le gouvernement de l'exploitation par longue taille dans le ouest canadien, a contracté McIntyre Mines Ltée. afin d'entreprendre l'ingénierie et le dessin d'un système se rapportant à leur mine 9G-4 qu'on avait citée comme emplacement possible.

Il y avait beaucoup de problèmes avec le système d'exploitation de longue taille dans la couche no. 4 à Smokey River Mines au début des années 1970. Les principaux problèmes avaient trait à l'équipement qui était disponible alors. Il y avait de graves problèmes avec les toits, ce qui a résulté dans la terminaison des activités d'exploitation par longue taille. De récentes avances dans la construction d'équipement de longue taille ont suscité une réévaluation du potentiel de la longue taille, et l'étude d'ingénierie suggère que cela pourrait être réintroduit avec succès. L'on peut catégoriser les travaux d'ingénierie en trois étapes: le développement d'un concepte général, la préparation de paramètres de planification pour les réserves dans la mine 9G-4, et la préparation d'un dessin précis pour les longues tailles de la 9G-4.

La géologie de l'emplacement en vue est une paire d'anticlines et de synclines avec pentes entre 4 degrés et 30 degrés. L'emplacement contient des réserves suffisantes dans la couche no. 4 , qui a une moyenne de 20 à 22 pieds d'épaisseur, ce qui satisfera aux exigeances d'un programme minier de 5 ans.

D'autres réserves se trouvent dans des emplacements adjacents. Le travail géotechnique a confirmé la résistance de charbon à différents horizons dans la couche et a aussi identifié la position et les caracteristiques d'une bande de charbon mou qui se trouve à quelques 12 ou 14 pieds en-dessous du toit de la couche. La possibilité de foudroyage a été étudiée d'après le carottage et l'exploitation de la même couche dans une mine voisine.

Après avoir étudié les possibilités diverses, un plan d'exploitation par longue taille rabattante avec deux développements d'entrée a été sélectionné afin d'en faire un usage maximum du savoir et de l'équipement en main actuellement. Des voies d'accès seraient construits jusqu'au toit de la couche et le soutènement se ferait avec des boulons de toit.

Une longueur de taille de 550 pieds a été recommandée, étant données les considérations du foudroyage, la capacité de l'équipement, la géométrie de réserve et la possibilité d'exploitation future dans la couche no. 10 au-dessus.

Avant d'introduire la longue taille, du materiel supplémentaire et des entrées de ventilation seraient fournis. Les panneaux seraient alignés dans la direction de la couche avec les fronts en plein pendage. Les dix pieds supérieurs de la couche seraient exploités en se servant d'une haveuse à deux sens et d'un soutènement à bouclier ou d'un soutènement mécanisé à piles.

On discutera aussi des offres de développement , d'équipement et de transferts de front.

On estime que le rendement quotidien sera de 100 pieds effectué par trois postes, à 208 tonnes fortes de brut poste/machine. La performance de la haute taille est projetée à 9.2 (taux de cisaillement) par jour par trois postes, ce qui donnera 4,370 tonnes fortes de brut. Le développement et la production des trois panneaux sont estimés à 3.8 millions de tonnes fortes de cru dont 87 % provient de longue taille et 13 % du développement. Basé sur le charbon brut, la productivité pendant la projet de cinq ans est estimée à 16 tonnes par poste/homme à partir du développement, à 53 tonnes par poste/-homme à partir de la haute taille, et à 25 tonnes par poste/homme pour tous les employés de la mine. La direction du projet, la possibilité de recherche additionnelle ainsi que les coûts opérationnels et le prix d'installation seront fournis. Etant donné le prix de vente, et l'estimation de la mise de fonds et du coût des installations, la valeur nette actuelle du projet est estimée à $10.2 millions.

Etant donné les bénéfices éventuels pour l'industrie houillère de l'ouest canadien, et étant donnés les risques d'ordre technique et financier qui se présentent lorsqu'on introduit la technologie moderne de longue taille, on recommanderait que l'industrie se joigne au gouvernement pour faire une démonstration commune.

Applications spéciales de la longue taille

Une série d'exemples spécifiques pour chaque site illustre la gamme de conditions dans lesquelles la technique de l'exploitation par longue taille pourrait s'appliquer. Les cas illustrés comprennent l'exploitation en couche épaisse à tranche simple suivant la direction de la couche, à tranches multiples avec foudroyage secondaire; extraction de couches minces ; et exploitation de la couche fortement inclinée en direction horizontale et en remontage.

Un exemple d'exploitation à tranche simple de couche épaisse en direction horizontale se trouve à l'opération de longue taille à Carbon County Coal Company à Hanna, Wyoming.C'est aussi le cas (tranches multiples) chez Daw Mill Colliery au Royaume-Uni, les comtés du centre d'Angleterre de la NCB, où la tranche supérieure d'une couche épaisse est exploitée par le système de longue taille avançante, et une seconde tranche , en rabattante. Quant à l'exploitation par longue taille d'une couche épaisse et la récupération secondaire par foudroyage, on se sert comme point de référence de l'exemple des opérations Blanzy à Charbonnage de France dans les gisements houillers du Midi.

Les opérations de North River Energy Company dans l'Alabama aux Etats-Unis démontrent le potentiel de longue taille dans les applications de couches minces.

L'exploitation des couches en pointe raide en direction horizontale est illustrée par un exemple de la mine Warndt dans la région de Saar dans l'Allemagne de l'ouest, et l'exploitation des couches en pente raide en plan incliné est illustrée par référence au gisement houiller dans la Lorraine en France.

La génération actuelle d'équipement pour l'exploitation par longue taille fournit des occasions d'effectuer ce genre d'exploitation sous une variété de conditions en dehors de celles qu'on considère conventionnelles.

Démonstration d'exploitation par longue taille chez Snowmass

On décrira une démonstration réussie d'exploitation par longue taille dans une couche inclinée de 30 degrés aux opérations souterraines houillères chez Snowmass Coal près de Carbondale, Colorado. Cette opération se déroule actuellement en coopération avec le Département de l'énergie des Etats-unis.

On examinera les principaux critères en faveur de la planification des couches inclinées de longue taille. On parlera aussi de la conception d'un projet de mine,et on parlera également des problèmes associés au développement des entrées des couches inclinées.

On décrit en détail la sélection d'équipement pour le système de longue taille pour le front de 350 pieds. Le système consiste en un transporteur jumeau armé en chaine de 22 mm hors-bord, une haveuse à tambour à deux sens avec un système de transport souterrain à haute puissance et sans chaîne qui fonctionne sur le système "troika". La méthode pour contrôler le transporteur et les boucliers sur un mur avec une pente qui dépasse les 30 degrés est aussi décrite,avec d'autres aspects de l'opération,de la sécurité et de l'entrainement.

La moyenne de production par machine / poste sur une période de trois mois a été de 719 tonnes brutes avec une productivité de 65 tonnes brutes par personne/poste (de longue taille jusqu'à l'extérieur).

LONGWALL MINING IN WESTERN CANADA

TWO DAY SEMINAR 14/15 NOV 1983

PROGRAM OUTLINE

DAY ONE

From	To	Subject	Speaker
0830	0845	Introduction	G. Zahary (Canmet)
		Why Longwall?	
0845	0915	- The Resource Recovery Perspective	D. Henderson (ERCB)
0915	0945	- Safety	H. Sahay (OHS)
0945	1015	- Production & Productivity	I. Muirhead (Monenco)
1015	1030	Coffee.	
1030	1145	Geological & Geotechnical Considerations for Longwall Mining	G.R. Jordan (Norwest)
1145	1245	Lunch.	
1245	1400	Mine Design	J. Greenwell (Gullick Dobson)
1400	1415	Coffee.	
1415	1530	Equipment	H.D. Owen (Norwest)
1530	1630	Discussion.	

LONGWALL MINING IN WESTERN CANADA

TWO DAY SEMINAR 14/15 NOV 1983

PROGRAM

DAY TWO

From	To	Subject	Speaker
0830	1015	Case Study - SRC Demonstration Longwall	T. Robson (SRCL)
1015	1030	Coffee.	
1030	1145	Discussion.	
1145	1245	Lunch.	
1245	1345	Special Longwall Applications	J.P.L. Bacharach (Consulting Mining Engineer)
1345	1445	Case Study - Snowmass Demonstration Longwall	J. Reynolds (Snowmass Coal)
1445	1500	Coffee.	
1500	1630	Discussion and Summing-Up	Panel

LONGWALL MINING IN WESTERN CANADA

TWO DAY SEMINAR 14/15 NOV 1983

LIST OF PARTICIPANTS

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LONGWALL MINING IN WESTERN CANADA
TWO DAY SEMINAR 14/15 NOV 1983

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LONGWALL MINING IN WESTERN CANADA

OPENING ADDRESS

Presented by:
G. Zahary
Manager
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CANMET
November, 1983

LONGWALL MINING IN WESTERN CANADA

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OPENING ADDRESS

On behalf of the Canada Centre for Mineral and Energy Technology (CANMET) welcome to the seminar: Longwall Mining in Western Canada. The seminar is an outcome of an engineering feasibility study to set-up a demonstration of a longwall mining system in this region. In that sense it is a second choice for a number of the lecturers who will be speaking to you in the next two days. First choice would have been to have a longwall system working. All of this is by way of drawing your attention to the fact that your instructors are prepared to practice what they teach and you should take advantage of this capability.

In addition I encourage you to participate in the seminar by raising questions not addressed by the instructional material. Establishing a longwall system in Western Canada is likely to require some pooling of resources since the cost of the system appears to be too high for any one organization to manage alone. If resources are pooled then the demonstration must meet the needs of the participating organizations. As I see it this calls for a demonstration of the reliable production capacity of the system and a ranking of the governing constraints. To plan the demonstration a preliminary selection of perceived constraints must be made. We hope that you can make a contribution here.

The seminar is presented by the University of Calgary and sponsored by CANMET of Energy, Mines and Resources Canada. CANMET operates Coal Research Laboratories (CRL) with facilities in Edmonton, Calgary, Sydney and with headquarters in Edmonton. The longwall project was our first attempt at the "demonstration" approach to participating in the improvement of coal mining technology in Western Canada. It did not proceed because of the recent decline in coal markets. The value of this approach to improving techology remains to be tested. Funding for this seminar was provided from the START (Short-Term Assistance in Research and Technology) program. This is a special two year, $5 million program funded by EMR to help industry directly in the solution of specific short-term problems in production and productivity. Special seminars such as this represent one of the approaches adopted under the program.

With that let's get started.

LONGWALL MINING IN WESTERN CANADA

WHY LONGWALL?

SAFETY ASPECT

Prepared by:
H. Sahay
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Nov/83

INTRODUCTION

We are undoubtedly very fortunate in Alberta to be blessed with vast reserves of coal. With depleting resources of oil and gas, coal will have to assume a major share of the energy supply system both domestically and internationally. Its development, however, will indeed require use of innovative technology and favourable economic environment.

"Longwall mining" is one of the areas that must be seriously examined to mine our coal more safely, efficiently and competitively. The success of this mining method abroad is definitely impressive in terms of both the safety and productivity. Recent studies conducted by MSHA indicated that a reduction of 40% was noted in the total disability injuries when compared with continuous miner operations. Similarly there was a potential of 90% reduction in roof fall and 60% in electrical injuries. The injuries related to material handling, hydraulic repairs and failures, machinery and fall of materials, however, showed an increase of 20 to 50% over the continuous miner operations. With training and experience this category of injuries could be substantially reduced. Most importantly, no fatalities were recorded in the two year period the study was conducted for.

A reduction in accidents has been equally impressive in the U.K. Fatalities in 1950 were 81. By 1960 with 38% mechanization it was reduced to 55 and in 1970 with 92% mechanization to 17. The figure for 1977 is 5. Over the same period the accident rate fell from 458 to 106.

Productivity wise, output from the longwall operations in the U.S.A. averaged about 800 tons per working shift in 1979 against 225 tons for the continuous miner operations. Accordingly, it is estimated that with every 10% replacement of continuous miner operations in the U.S.A. there would be 20% increase in underground productivity. The trend towards longwall mining is quite evident from the fact that the rate of growth in the number of longwall operations in the U.S.A. doubled from 6 sections recorded over 1972-1975 to 12 in 1977-1979.

According to many, the reductions in the accidents in longwall mining is believed to have resulted mainly from the introduction of mechanization to longwall faces. This in turn provided impetus to the development of better and reliable equipment and practices which saw the introduction of face conveyor systems, trapped rail shearing and trepanning machines, limited web seam extraction, controlling unsupported ground at the face, the introduction of face support systems, the development of mechanized packing and stowing of gate areas, the elimination of machine stable holes, the elimination of chain driven machines and the efforts to provide adequate ventilation and dust suppression facilities to improve the working environment and not least the organization of a training system and practice to ensure that all workers understood what was required of them.

Many mining and other engineers have indicated that the important non-technical aspect of a longwall face as far as safety is concerned, is that once the face has been laid out and installed, only by controlled modification can the shape or practice on such a face be changed. This is quite different from the earlier practices in room and pillar extraction workings.

One of the major factors which has helped the success of longwall mining greatly, is its amenability to an engineering approach and control. In room and pillar method, much was left on the personal judgement of the miners and their immediate supervisors, especially when it came to the assessing and monitoring of the roof condition.

ACCIDENT STATISTICS

Recently a study was conducted by MSHA under the heading of "U.S. Longwall Technology and Regulations" to assess the potential of longwalls to improve health and safety and productivity. The study involved a sample of 24 longwall sections and was carried out on the data collected for a two year period (1978-1979) as per MSHA's Part 50 reporting procedures. Following are some of the results and conclusions derived.

TABLE 1

A RELATIVE INDEX COMPARISON OF LONGWALL INJURIES WITH CONTINUOUS MINERS

Type of Injury	Relative Index
Fatalitity	0
Total Disability	0.6
Disabling Injury	1.09
Non-Disabling Injury	1.24

(Source: MSHA)

Table 1 compares the relative index of longwall mining injuries with continuous miner operations. The relative index represents a ratio of injuries experienced in longwall sections to corresponding injuries for producing equivalent amounts of coal by continuous miners. For example, the total disability relative index of 0.6 represents a 40% reduction of total disability in longwalls when compared with continuous miner operations.

Relative index for disabling injury showed a small increase of 9% for longwall mining over continuous miner operation.

The index for non-disabling injury however recorded 14% increase over the continuous miner operations.

TABLE 2

A RELATIVE INDEX OF LONGWALL DISABLING INJURY ACCIDENTS

Accidents	Relative Index
Electrical	0.35
Roof Fall	0.05
Handling Materials	1.22
Hydraulic Sources	1.30
Machinery	1.33
Fall of Materials	1.50

(Source: MSHA)

Table 2 compares the relative index of longwall disabling injuries for the various injury categories. Disabling injuries associated with electrical and roof fall accidents showed a marked decrease in longwall operations. Machinery and material related accidents showed an increase in longwall operations.

Similarly longwalls appear to have the potential to achieve approximately 90% reduction in roof fall injuries and approximately 60% reduction in electrical injuries.

For other injury categories, longwalls appear to produce 20-50% more injuries related to handling of materials, hydraulic repairs and failures, machinery and fall of materials when compared with continuous miner systems. These injury categories generally depend on the amount of training received by a miner and the extent of the miner's experience on the job and thus they could be reduced.

Table 3 - Summary of Reportable Accidents at all Longwall Faces During the Period 1975-1979 - U.K.

		Roadhead Areas	Face Area Excluding Roadheads	All Face Accidents
1.	Falls to ground	152	238	390
2.	Rope haulage	14	26	40
3.	Chain conveyors	62	42	104
4.	Belt conveyors	3	-	3
5.	Other haulage/ conveyors	3	-	3
6.	Power-loaders:			
	(a) haulage chain	7	47	54
	(b) others	8	34	42
7.	Roadway cutter-loaders/rippers	3	-	3
8.	Mechanical loaders	14	-	14
9.	Other machines	8	4	12
10.	Power supports	7	54	61
11.	Use of tools/ appliances	18	9	27
12.	Falling objects:			
	(a) supports	33	21	54
	(b) others	11	12	23
13.	Stumbling, falling, slipping:			
	(a) slipping, falling over fixed equipment	10	5	15
	(b) falling from a height of plus one metre	17	1	18
	(c) others	4	2	6
14.	Explosives	2	2	4
15.	Other accidents	6	12	18
	TOTALS	382	509	891

(Source: Inspectorate U.K.)

Table 4 - Location of Falls of Ground Accidents at all Longwall Face-ends - U.K.

Location	Frequency %
1. The fast-end	5.3
2. Roadhead:	
(a) ahead of ripping	24.7
(b) at the ripping	34.7
(c) outbye of ripping	12.0
3. The stable entry	6.0
4. Ahead of front supports	9.3
5. The waste edge	0.7
6. The roadside pack area	7.3

(Source: Same as Table 3)

Falls of ground account for 40% of all accidents occurring at face-ends. Their relationship to location is well illustrated in the above table. The majority of ground falls appear to occur in the roadhead area during ripping.

TABLE 5 - Falls of Ground Accidents at Face-ends

Year	Advancing Faces			Retreating Faces		
	Number of Faces	Number of Accidents	Ratio Accidents/ Faces	Number of Faces	Number of Accidents	Ratio Accidents/ Faces
1975	671	43	0.064	102	nil	nil
1976	654	35	0.055	107	1	0.009
1977	623	39	0.066	102	1	0.010
1978	559	26	0.047	100	1	0.010
1979	573	25	0.044	114	1	0.009

(Source: Inspectorate U.K.)

It is clearly evident that "Retreating Faces" have less accidents involving "falls of ground" than "Advancing Faces".

TABLE 6

Longwall Accidents,* 1978-1982

By Location

	1978	1979	1980	1981	1982	Total	Percent
Face	280	363	490	370	332	1835	55.3
Face Support	34	59	67	38	27	225	6.8
Not Stated	26	26	38	32	48	170	5.1
Other	160	210	238	270	212	1090	32.8
Total	500	658	833	710	619	3320	100.0

*Includes fatalities, non-fatal days lost, no days lost, non-injuries and occupational illnesses.

(Source: MSHA)

As can be seen, a major part of the accidents took place at the face. Although not shown here, other areas which had significant accident frequency were intersections, along highways, shops, etc.

TABLE 7

Longwall Accidents,* 1978-1982
By Accident Classification

	1978	1979	1980	1981	1982	Total	Percent
Handling Materials	177	256	268	226	214	1141	34.4
Machinery	81	111	154	108	86	540	16.3
Fall of Roof	46	58	102	78	59	343	10.3
Handtools	48	49	97	59	66	319	9.6
Slip or Fall	37	56	69	83	66	311	9.4
Powered Haulage	30	41	41	56	54	222	6.7
Fall of Face, Rib	12	10	22	15	11	70	2.1
Falling, Sliding Material	17	9	12	6	12	56	1.7
All Other Classifications	52	68	68	79	51	318	9.5
Total	500	658	833	710	619	3320	100.0

*Includes fatalities, nonfatal days lost, no days lost, non-injuries, and occupational illnesses.

(Source: MSHA)

This shows that 34.4% of the longwall accidents were in "materials handling" with machinery and fall of roof following it (16.3% and 10.55% respectively). The leading sources of the materials handling accidents were mineral items such as pipe, wire, nails, I-beams, and timbering items such as posts, caps, headers and timbers. The most common parts of the body injured were fingers, back, hands, ankles and feet.

Machinery accidents were the second highest class of accidents. Longwall jacks, ram jacks, shields, and chocks are the leading sources of machinery accidents. Two machinery fatalities occurred at the face. The first was when a plow guide struck a jack and crushed a miner; the other when a rock fouled the shear and struck the miner who was lying across the machine.

Roof fall injuries were primarily caused when pieces of coal or rock fell between the chocks or shields, striking the miner. One of the three roof fall fatalities occurred in this manner. Of the other two, one occurred in a roofbolted area and the other at the longwall face during preparation for a move.

Hammers, sledges, scaling bars, axes, and other smaller handtools were most commonly involved in the handtool accidents.

Most slip and fall accidents occurred while walking or running; climbing up, down, or over equipment; carrying materials; or using hand tools.

Powered haulage accidents on longwall sections were primarily attributed to belt conveyors and longwall conveyors and, to a much lesser extent, locomotives, shuttle cars, and rail cars. One fatality involved a collision between a moving locomotive and a stalled locomotive.

TABLE 8

Longwall Accidents,* 1978-1982

By Occupation

	1978	1979	1980	1981	1982	Total	Percent
Jacksetter	133	146	165	157	102	703	21.2
Shear/Plow Operator	54	64	108	79	74	379	11.4
Laborer (Non-face)	38	58	72	51	55	274	8.3
Laborer (Face)	26	49	52	53	37	217	6.5
Mechanic/Repairman (Face)	21	32	53	27	35	168	5.1
Section Foreman (Face)	15	18	41	20	12	106	3.2
Mechanic/Repairman (Non-face)	16	21	21	20	19	97	2.9
Timberman/Propman (Face)	24	17	16	12	17	86	2.6
Roofbolter (Face)	8	14	19	27	10	78	2.3
Belt Conveyor Man	11	12	11	22	17	73	2.2
Labor Foreman (Non-face)	5	21	18	10	10	64	1.9
Electrician	9	15	13	12	13	62	1.8
Timberman (Non-face)	11	6	9	16	9	51	1.5
Shuttle Car Operator	1	15	13	14	6	49	1.5
Utilityman	9	3	10	14	13	49	1.5
Motorman	3	17	7	12	6	45	1.4
Unknown	14	6	8	10	17	55	1.7
Other	77	116	131	116	125	565	17.0
Not Coded	25	28	66	38	42	199	6.0
Total	500	658	833	710	619	3320	100.0

*Includes fatalities, nonfatal days lost, no days lost, non-injuries, and occupational illnesses.

(Source: MSHA)

The data collected on the basis of occupations of the miners injured indicated that jacksetters received 21.2% of the accidents with shear/plow operations 11.4%; laborers, face and non-face 14.8%; mechanics, face and non-face 8%; and section foremen 3.2%.

Jacksetters were most commonly injured by material falling off shields or chocks. Rocks, cribs, and headers became dislodged when the hydraulically powered supports were being repositioned. In low coal, miner's hands were often crushed between the roof and the ascending chock or shield.

The work station for shear operators is normally very close to the face where they are vulnerable to injuries from flying coal caused by pressure bumps, or by the shear picking up and throwing loose coal and debris. Other operators were struck by rock or coal falling between roof supports.

The most common cause of injuries to laborers was the fall of face or rib. These injuries involved activities such as timbering operators, clean-up of coal from alongside longwall conveyors, advancing longwall supports, assisting mechanics and moving equipment outbye the face.

Mechanics were primarily injured while lifting, dragging and pulling heavy objects while in cramped quarters. Applying too much pressure on tools caused either the tool to break or the mechanic to lose his grip on the tool and slip or fall.

Maintenance and servicing of equipment by mechanics and laborers has resulted in numerous loss-of-finger injuries. Two examples of these types of accidents are as follows. When changing a jack piston, some miners stick their fingers in the hole to check pin alignment. If the piston slips, part of a finger is amputated. The other example involves miners putting shear pins into shear hubs. This action may allow a glove to be caught pulling their fingers into the hub.

Section foremen were usually injured by flying debris while observing operations in close proximity to the operating shear or plow, or while performing non-supervisory work.

Again, Table 9 showing accidents by activity confirms the earlier findings that material handling accounts for the highest frequency in longwall mining. With training, substantial improvement can be made.

TABLE 9

Longwall Accidents,* 1978-1982

By Activity

	1978	1979	1980	1981	1982	Total	Percent
Handling, Load-unload Materials	75	117	157	147	122	618	18.6
Walking/Running	23	53	78	64	55	273	8.2
Operate Longwall Shear, Plow	40	51	69	61	45	266	8.0
Machine Maintenance/ Repair	50	54	63	43	50	260	7.8
Advancing Longwall Roof Support	34	37	69	48	39	227	6.8
Non-powered Handtools	31	32	50	43	49	205	6.2
Handling Timber	21	35	28	40	28	152	4.6
Moving Equipment	22	16	31	18	9	96	2.9
Handload/Shovel/Muck	12	14	24	20	15	85	2.6
Handling Coal	10	16	26	9	16	77	2.3
Cleaning	10	10	11	5	4	40	1.2
Unknown	13	8	4	4	4	33	1.0
Other	134	187	157	170	141	789	23.8
Not Coded	25	28	66	38	42	199	6.0
Total	500	658	833	710	619	3320	100.0

*Includes fatalities, nonfatal days lost, no days lost, non-injuries, and occupational illnesses.

(Source: MSHA)

ENVIRONMENTAL CONCERNS - LONGWALL FACES

Serious attempts to reduce dust and hence pneumoconiosis began in the U.K. in the 1950's almost coincidentially with the surge towards mechanization. The NCB set up its Pneumoconiosis Field Research Group in 1952 to determine what kinds and how much dust caused pneumoconiosis and to establish what environmental conditions should be maintained on longwall faces to prevent disablement of workers. Dust standards were introduced in 1970 vastly improving the conditions so as to dramatically reduce the incidence of pneumoconiosis in young mine workers.

Figure (1) shows a graph of the trend of new pneumoconiosis cases for the years 1958 to 1979 and illustrates that increased production and productivity which occurred during the period could be achieved with increased health safety.

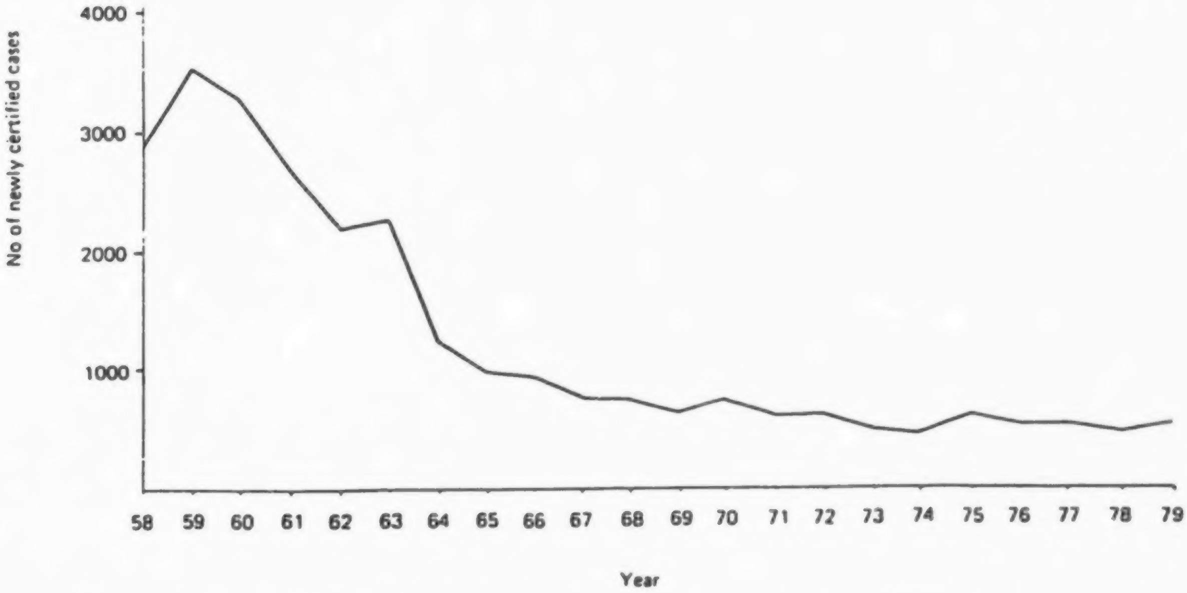

Fig. 1 Trend of pneumoconiosis cases (new) 1953-79

(Source: Inspectorate - U.K.)

The experience in the U.S.A. with dust control at longwalls has been very encouraging as one could note in Table 10. The average respirable dust (mg/m3) has varied from 3.6 to 2.3. There seems to be some relationship in tonnage mined per shift to the level of respirable dust.

During the recent visit to U.S. longwall operations, we were pleased to note that considerable reduction has been achieved in dust level at various operations meeting the present standard. The curtain and water jets designed by U.S.B.M. has been particularly successful.

TABLE 10

SAMPLE PRODUCTION AND RESPIRABLE DUST DATA OF A TYPICAL DOUBLE DRUM SECTION WITH WATER SPRAYS

Day	Production Tons/shift	Average Respirable Dust mg/m^3
1	690	3.6
2	540	3.0
3	520	2.5
4	490	2.5
5	440	2.3
6	460	2.2
7	470	2.8
8	450	2.6
9	420	2.5
10	370	2.3
11	350	2.3
12	350	2.3
13	350	2.3

WHY LONGWALL?
THE RESOURCE RECOVERY PERSPECTIVE

by

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Coal Department
Energy Resources Conservation Board

1 INTRODUCTION

Does longwall mining improve recovery of the resource?

A very interesting question indeed.

One which, along with several other major questions, must be answered before exceedingly large sums of money are committed to a longwall project in western Canada.

In this presentation, I hope to provide information which will enable this gathering to arrive at it's own answer.

However, it may be of some assistance at this stage for you to be aware of my own opinion in the matter.

At best, I feel I can only offer you a "definite maybe" or a "qualified yes".

2 TERMINOLOGY

Before delving too deep into the topic, I would like to briefly address myself to the terminology used by the E.R.C.B. in reference to the coal resource.

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The Board has adopted a slightly modified version of the terms and definitions established by the 1978 Joint Task Force on Uniform Resources Terminology.

Figure 1 shows the Board's terminology in graphic form.

During subsequent discussion in this presentation our interests will be in three areas:

- the "Established Resource" - defined as a body of coal that has been specifically delineated by drilling, trenching, driving adits, mine development operations or other exploratory work, but including some judged to exist contiguously on the basis of geological, seismic or other information.
- the "Initial Reserve" - defined as that portion of the Established Resource (prior to any production) considered as recoverable by current technology under present or anticipated economic and social conditions.
- the "Underground - Mineable Reserve" which can be defined as that part of the Initial Reserve which is too deep or otherwise too unfavourable for surface mining.

It should be noted that this terminology was derived purely for reserve calculation purposes in the Province of Alberta and that the definitions may be somewhat different to those used in the reserve calculations for a particular deposit.

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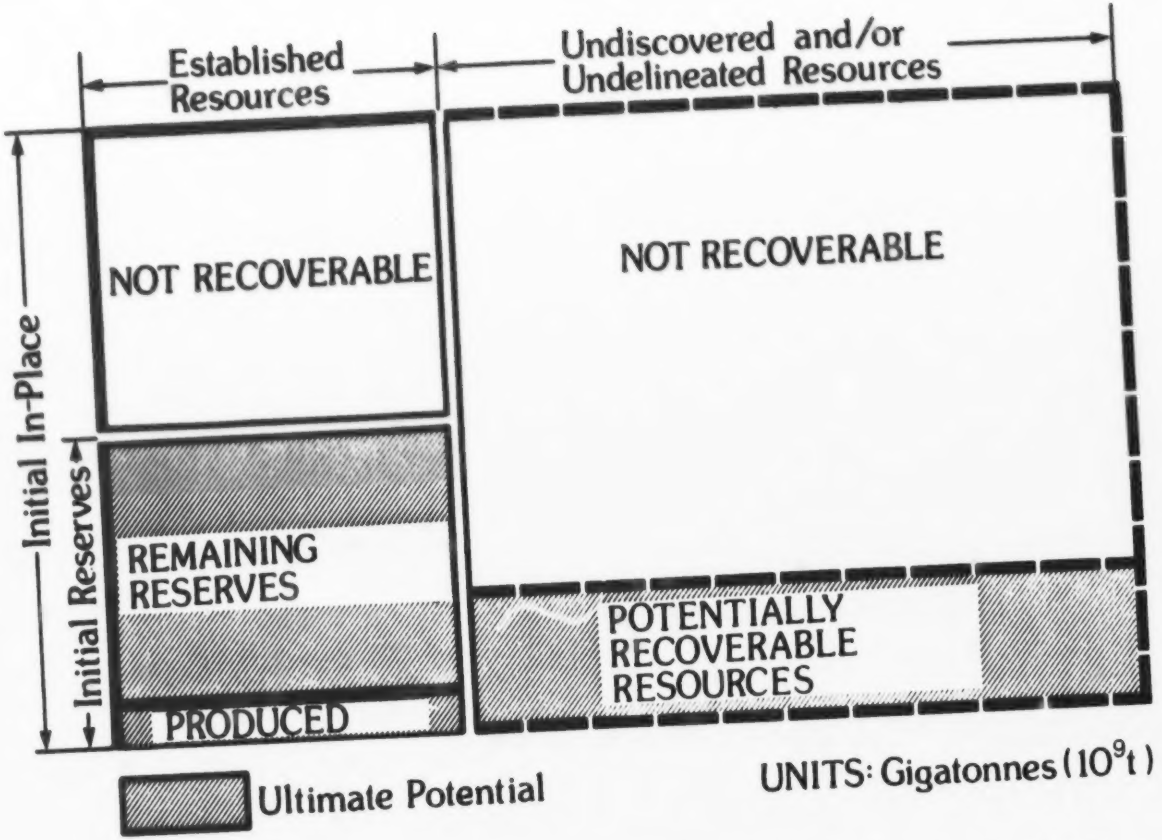
Established Resources
Undiscovered and/or Undelineated Resources
Initial In-Place
Initial Reserves
NOT RECOVERABLE
NOT RECOVERABLE
REMAINING RESERVES
PRODUCED
POTENTIALLY RECOVERABLE RESOURCES
Ultimate Potential
UNITS: Gigatonnes (10⁹t)

FIGURE 1 SCHEMATIC REPRESENTATION OF ERCB RESOURCE TERMINOLOGY

3 RECOVERY FACTORS

The Board's calculations for Underground-Mineable Reserves utilize subjective recovery factors which take into account the deposit and mining problems as they relate to the region and the thickness of the seam.

These are summarized as follows:

Region	Seam Thickness	Effective Recovery Factor
Mountain	Thin (0.6-1.5m)	0.00
	Medium (1.5-3.6m)	0.38
	Thick (+3.6m)	0.25
Foothills	Thin	0.00
	Medium	0.53
	Thick	0.35
Plains	Thin	0.00
	Medium	0.68
	Thick	0.45

It should be stressed that these recovery factors are anticipatory in nature and should therefore not be construed as representing recovery factors achieved from actual mining of Alberta coals.

There is, in fact, little information existing as to the actual recoveries achieved with respect to both past and present mining.

This does leave us, of course, with the problem of an insufficient data base with which to evaluate the possible impact of longwall mining upon resource recovery.

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To assist us in this dilemma, it will therefore be necessary to employ a subjective analysis of longwall mining along with the other mining systems common to, or applicable to, western Canada.

4 HOW DOES LONGWALL MINING INFLUENCE RECOVERY?

I would suggest to you that there are two ways in which longwall mining could influence recovery of the resource:

- by enabling coal, which would otherwise be considered unmineable (by any other mining system), to be placed in a mineable reserve category. Perhaps we could refer to this as "upgrading unmineable into a mineable category".
- by influencing the percentage of mineable reserves recovered by better utilization of the reserve area, i.e. improving the layout.

4.1 UPGRADING UNMINEABLE INTO A MINEABLE CATEGORY

At the risk of some over-simplification and generalization, I propose to isolate and consider a few of the more important parameters or factors essential in the selection of a longwall mining system and which also bear consideration with respect to resource recovery.

I also propose to consider these parameters as they apply to two other mining systems, i.e. room and pillar and hydraulic mining, and attempt to assign a number (from 1 to 3) to each mining

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system which will reflect where each system stands in the recovery "race".

Hopefully, such an analysis will enable us to answer the question posed at the beginning of this presentation.

The parameters, which I feel are of prime importance, are:

- seam thickness
- seam gradient
- depth of cover
- structural geology

4.1.1 SEAM THICKNESS

Western Canada is blessed with a wide range of seam thicknesses. While local thickenings of 60 to 90 metres do exist, they are not usually extensive enough to be considered for longwall. Accordingly, I will confine my comments to those seams with thicknesses ranging from 1.0 to 15 metres.

The following is what I consider to be the normal technical upper and lower limits of applicability of the three mining systems:

System	Limitation (in metres)		Assigned Recovery
	Min.	Max.	Potential
Room & Pillar	1.8	3.7	3
Longwall	1.0	4.2	2
Hydraulic	2.1	15	1

I would expect that this table would immediately create some consternation among the audience. And rightly so.

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We are all aware of examples where both room and pillar and longwall mining systems are successfully operating in seams in excess of 3.7 and 4.2 metres respectively, while achieving very creditable recoveries. However, such operations are usually aided by other parameters and/or special mining techniques. The limitations in this table are derived from an appraisal of the ability of the equipment to mine in one pass without the assistance of other factors.

Longwall's applicability and recovery potential would be greatly enlarged with multi-lift techniques - there is currently a demonstration of this technique underway at one of Mid-Continent's mines in Colorado - and with the use of the caving systems employed in France and Yugoslavia.

Nevertheless, by staying with these limitations, longwall mining is judged to be second, behind hydraulic mining, with respect to recovery of the resource.

4.1.2 SEAM GRADIENT

Seam gradients in western Canada vary from almost perfectly flat all the way up to vertical. Extensive substantially horizontal resources occur under the Prairies, while the Foothills and Mountain regions of Alberta and B.C. contain the full range of gradients.

I perceive the normal limitations of the mining techniques as follows:

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System	Limitation (in degrees)		Assigned Recovery
	Min.	Max.	Potential
Room & Pillar	0	16-18	3
Longwall	0	45-50	1
Hydraulic	10	Potentially Vertical	2

In general, room and pillar mining equipment is limited to operations on gradients of no more than 12 degrees. Cross-pitch roadways extend the applicability of the system to a maximum seam gradient of approximately 18 degrees. The use of cross-pitch roadways also result in undesirable pillar shapes.

In hydraulic mining, the need to develop fluming roadways in two directions dictates a minimum seam gradient of approximately 10 degrees.

Considerable success has been achieved in European mines, particularly in Poland and Germany, in adapting the present breed of longwall equipment in the mining of steep seams. 30 to 35 degrees (along the face line) is now quite common while a few faces are working in the 55 to 70 degree range. Quite subjectively, I have selected 50 degrees as the upper longwall limit.

Later in the seminar you will be hearing from Mr. Reynolds with respect to the Snowmass steep-seam demonstration project. Most of you should find Mr. Reynold's talk very interesting.

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Mainly because of the lack of experience and/or success in hydraulic mining of extremely steep seams, I have assigned a first place to longwall with respect to recovery potential.

4.1.3 DEPTH OF COVER

System	Limitations (in metres) Min.	Max.	Assigned Recovery Potential
Room & Pillar	60	500	3
Longwall	60	900	1
Hydraulic	60	650	2

I think we can all agree that, while it very much depends upon the nature of the overburden and strata, 60 metres is the usual minimum mining depth.

The maximum for room and pillar is very much dependant upon the ability of the pillars, to withstand the loads incurred by the depth of cover. This maximum generally appears to be somewhere around 500 metres.

Longwall faces have been operated at depths of 1100-1200 metres in Europe; however, for our purposes, 900 metres seems to be a reasonable maximum.

The maximum limit for hydraulic mining has been selected again because of the lack of experience at depths in excess of 650 metres. However, it should be noted that Westar Mining do have plans to exceed this depth of cover within a few years.

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Longwall mining appears to come out best with the consideration of this parameter.

4.1.4 STRUCTURAL GEOLOGY

Rather than attempt to define any limitations with this particular consideration, it would appear to be more appropriate to discuss the needs of the individual mining system with respect to structural geology.

Room and pillar is a fairly flexible system which can quite easily be adjusted in areas of unfavourable structures (steep limbs of synclines/anticlines). Quite substantial faults can usually be negotiated with ease provided the need for rock drivage is fairly limited.

On the other hand, longwall mining is quite inflexible with respect to layout, requiring a relatively large, well explored area with faults of only insignificant displacement (less than 1 metre).

Hydraulic mining would appear to fall in between longwall and room and pillar with respect to flexibility.

Without a doubt, the structural geology consideration is extremely critical with regard to longwall mining. Anything unfavourable (e.g. a number of 2 or 3 metre faults in the deposit) will render the resource unrecoverable by longwall unless a layout can be developed which successfully avoids such structures.

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In view of the foregoing, the following recovery potentials have been assigned:

System	Assigned Recovery Potential
Room & Pillar	1
Longwall	3
Hydraulic	2

4.2 EFFICIENCY OF USE OF THE MINEABLE RESERVE AREA

It is possibly appropriate at this stage to distinguish between the in-panel recoveries and the recovery from the entire mineable reserve.

4.2.1 IN-PANEL RECOVERIES

Let us first examine the in-panel recoveries.

System	% Recovery
Room & Pillar	85-95
Longwall	100
Hydraulic	75-90

Inherently, room and pillar mining sustains in-panel losses due to the need to leave remnant pillars for roof control and for the protection of the workers. The size of such pillars vary considerably according to the local conditions.

Hydraulic mining also incurs losses when the unsupported hanging wall collapses prior to completion of extraction of the individual "pull backs".

On the other hand, longwall (at least hypothetically) should incur no in-panel losses.

Accordingly the potential recovery from longwall surpasses both room and pillar and hydraulic mining.

4.2.3 OVERALL MINEABLE RESERVE RECOVERY

The requirement to leave inter-panel, roadway protection and other barrier pillars is usually dictated by strata control and other safety considerations. Personal preferences of the planning engineer are very influential in the establishment of inter-panel and main road protection pillars. Obviously any un-necessary pillars detract from maximizing recovery of the resource.

It would appear that there are very few differences between longwall, room and pillar and hydraulic mining with respect to the need for out-of-panel pillars. However, I would like you to consider the following:

- longwall mining can result in some savings with respect to main road requirements (hence inter-road pillars) due to the concentration of production effort in a fewer number of units. However, concentration of production can also result in higher ventilation requirements on each face, so increasing again the number of roads required.
- the employment of single or multi-entry access for longwall mining deserves some discussion at this juncture. While I

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have no doubt that John Greenwell will discuss this during his presentation, I feel it is important to recognize that multi-entry access, to the longwall face, seriously reduces recovery, e.g. re-used 3-entry systems at 30 metre centres will result in a loss of 23% of the mineable reserves with 170 metre panels. Single entry, with the possibility of very minimal inter-panel pillars, will result in substantial "savings" of the resource. Obviously the security of a single entry system must be carefully assessed along with the ventilation requirements of the unit.

- the presence of oil or gas wells, and whether they are producing or not, provides considerable difficulty to maximizing recovery with longwall mining. Room and pillar can certainly be somewhat more flexible in negotiating around such objects and would therefore have the potential for better recoveries.

- the subsidence profile from longwall mining (provided the inter-panel pillars are very minimal) has the potential for making this type of mining more acceptable in areas where critical surface facilities (e.g. pipelines, irrigation ditches, roads, etc.) occur. The haphazard leaving of pillars and the other artificial support remaining in the gob in room and pillar mining ensures a very unpredictable subsidence profile. While much research and trial work needs to be done in the Prairie coal, the potential exists for longwall to undermine ditches and

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pipelines without causing unacceptable damage, provided the appropriate engineering protection is carried out prior to mining. Should this be an acceptable and successful procedure, the adoption of longwall could ensure a high recovery factor in the Prairie coals.

5 CONCLUDING REMARKS

Does longwall mining improve recovery of the resource?

I'm quite sure that even if you have followed my reasoning with all due diligence and have also accepted my opinions, you are no closer to developing a categoric answer to the question than you were when I started this presentation.

However, I do hope that I have left you with some appreciation for my reasons for the "qualified yes".

We have been made aware of, through a recent longwall study in western Canada, that under site specific circumstances, longwall mining can lead to a dramatic increase in the percentage of the resource recovered (from 17.5 to 35.8%). It is extremely important that such figures are not transposed into representing the gains which can be achieved throughout western Canada.

Nevertheless, I do believe that longwall mining can improve resource recovery; but only marginally so.

Thank you for your kind attention.

WHY LONGWALL?

- PRODUCTION AND PRODUCTIVITY

by

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Calgary

LONGWALL MINING IN WESTERN CANADA

CALGARY, ALBERTA

14 & 15 NOVEMBER 1983

MEB 7957-2/2054

1.0 INTRODUCTION

This paper is intended to provide the reader with data on production and productivity aspects of the longwall mining system, to complement the preceding papers by David Henderson (Reserve Recovery) and Harry Sahay (Safety).

Later papers in this seminar will examine in detail, the specific aspects of the Longwall mining system. With this in mind, this paper provides brief details of the range and conditions of application of longwall mining and its major rivals in the underground field - room and pillar, and hydraulic mining methods. The basic system of longwall mining is described together with a look at world usage and summary of the main advantages and disadvantages. Manpower requirements, outputs and productivities are discussed and typical capital and operating costs given.

2.0 MINING SYSTEMS

There are three basic methods which can be applied to the underground mining of coal. These are longwall mining (advancing or retreating), room and pillar mining (including depillaring) and hydraulic mining.

Each of these methods can be applied within certain limits related to physical conditions in the coalfield. The most common of these factors are:

- Seam thickness
- Gradient
- Depth below surface

Table I shows the normal working ranges for these factors for the three stated systems.

TABLE I - LIMITING OPERATING CONDITIONS

Mining Method	Seam Thickness (m)	Seam Gradient (°)	Depth below Surface (m)
Longwall	0.6 to 5.5(1)	0° to 55°	20 m to 1200 m
Room & Pillar	1.0 - 4.0	0 to 20°	20 m to 500 m
Hydraulic	2.5 m +	9° to 90°	20 m to 1200 m

Notes: (1) Single lift working.

In addition to these three factors, consideration has to be given at each proposed mine site, to:

- types of rock between the seam and the surface;
- nature and strength of the roof strata over the coal seam;
- nature and strength of the floor strata below the seam;
- coal seam characteristics including impurities, cleavage, hardness, strength and methane emission;
- quantity of water likely to be encountered;
- presence of other coal seams (worked or unworked) above and below;
- subsidence limitations.

It will be appreciated that actual operations are affected by all these factors, which in turn will dictate where, within the three major factor ranges quoted, the specific mine will operate.

3.0 THE LONGWALL MINING SYSTEM

3.1 BASIC SYSTEM

The longwall mining system, in its simplest form involves the extraction of large blocks of coal in a single continuous slicing process. The extraction can be either an advancing or retreating operation. In the advancing method, the coal is worked away from the main entries into virgin ground, the face roadways being maintained in the mined out area behind the coal face. In the retreating system, the block of coal to be mined is outlined by developing the roadways first, out to the limit of the block, and then retreating the faces back towards the main entries. (see Fig. 1).

Advancing longwall mining offers the following advantages: (1) quick startup of full production, and (2) shorter entry service life, because the entries do not have to be ready before the mining process begins. The disadvantages are: (1) high cost for packwalls; (2) abutment pressures have a full impact on the entries, possibly leading to excessive entry support and maintenance problems; and (3) methane liberation may be higher, because no bleeding has taken place during the entry development process and the danger of spontaneous combustion from air leakage through the packwalls into the sealed gob area is greater.

Retreating longwall mining has the following advantages: (1) it reduces entry maintenance, because the entries are abandoned shortly after they come under the influence of the forward abutment load; (2) it allows proper bleeding of the gob area (3) it reduces the danger of spontaneous combustion; (4) it assures that entry development will not hinder the face operation and allows positive control of the ventilation;

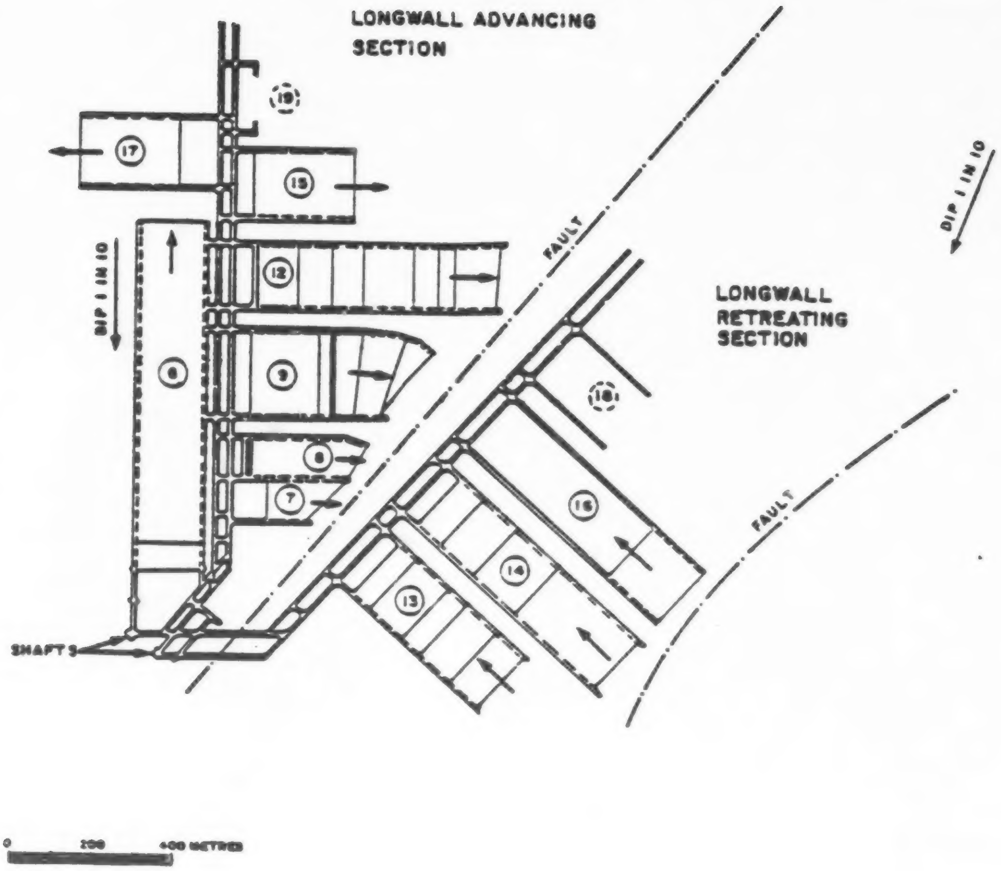

LONGWALL ADVANCING SECTION
19
17
15
12
DIP 1 IN 10
6
9
8
7
FAULT
LONGWALL RETREATING SECTION
18
16
14
13
DIP 1 IN 10
FAULT
SHAFTS
0
200
400 METRES

FIGURE - 1 : UNDERGROUND MINE SHOWING TYPICAL LONGWALL ADVANCING AND RETREATING SYSTEMS and most important (5) it provides advance knowledge of geological conditions. Its disadvantages include: (1) the development of entry systems in advance of the mining operation causes a delay in initiation of production, and (2) under unfavorable conditions (soft bedrock, thick overburden), a considerable number of entry maintenance problems may be experienced before full production starts.

The number of face roadways required to service a longwall face varies according to the mining regulations and custom and practice in each country. For example, in Europe and Canada only one roadway at each end of the face is required, whereas in the U.S.A. three is usually considered as a minimum.

The typical components of a longwall face, whether advancing or retreating are shown in Figure 2. These are:

(i) A coal cutting machine(s), usually a shearer.

(ii) A flexible chain conveyor (AFC) which transports the cut coal along the face; provides a track for the shearer to travel upon; often incorporates the structure which the shearer uses to haul itself along the coal face, and which forms the anchorage against which the powered supports advance themselves.

(iii) Powered hydraulic supports (including an electro/hydraulic power pack) which support the roof for the length of the face.

(iv) Modified powered supports for use at the ends of the face.

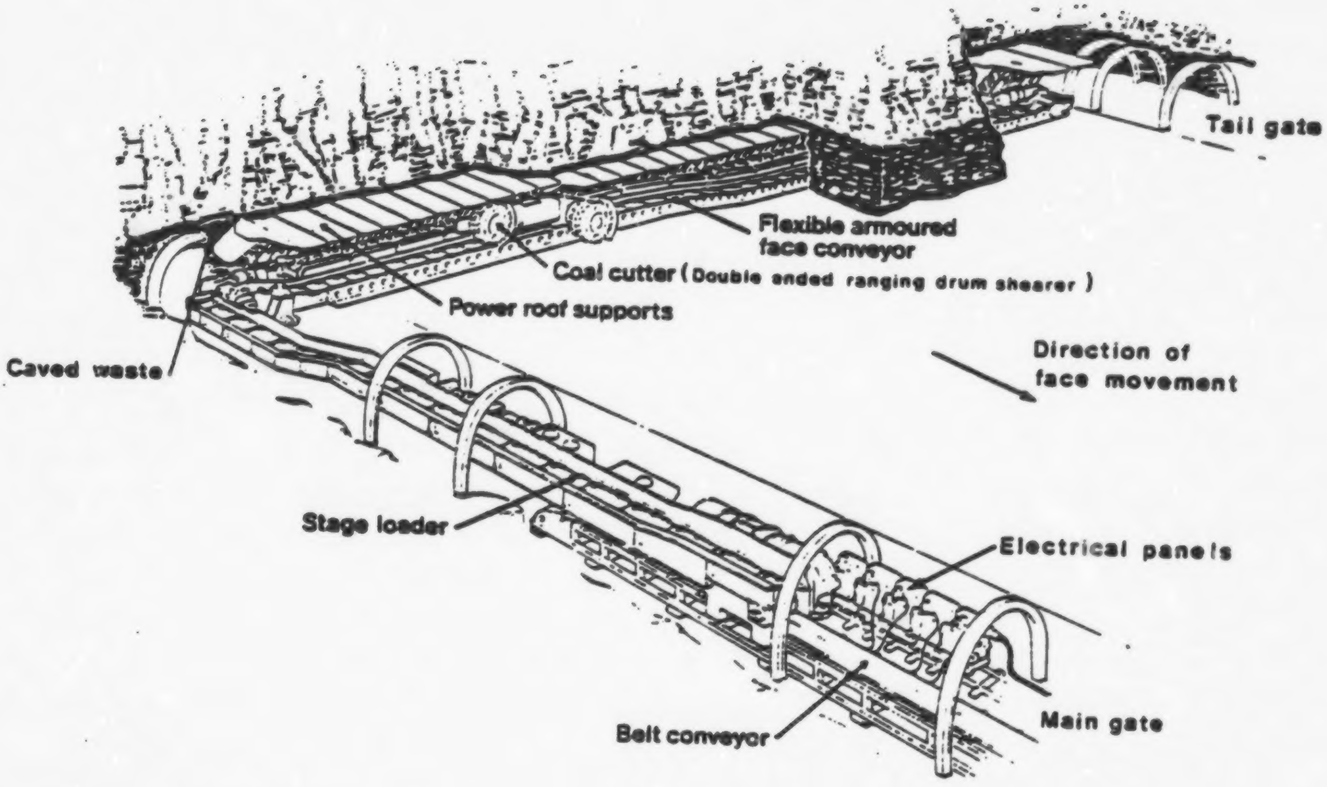

Tail gate
Flexible armoured face conveyor
Coal cutter (Double ended ranging drum shearer)
Power roof supports
Caved waste
Direction of face movement
Stage loader
Electrical panels
Main gate
Belt conveyor

FIGURE 2: TYPICAL RETREATING LONGWALL FACE SHOWING MAJOR EQUIPMENT COMPONENTS

(v) A chain conveyor or 'stage loader' situated in the main gate roadway which transfers the coal from the face AFC to the main gate belt conveyor.

(vi) A belt conveyor in the main gate which travels the length of the mining panel, and transports the coal to the main haulage system of the mine (usually conveyors or mine cars and locomotives).

(vii) Electrical equipment to power and control the above equipment.

(viii) Communications and signalling equipment.

(ix) Face lighting systems.

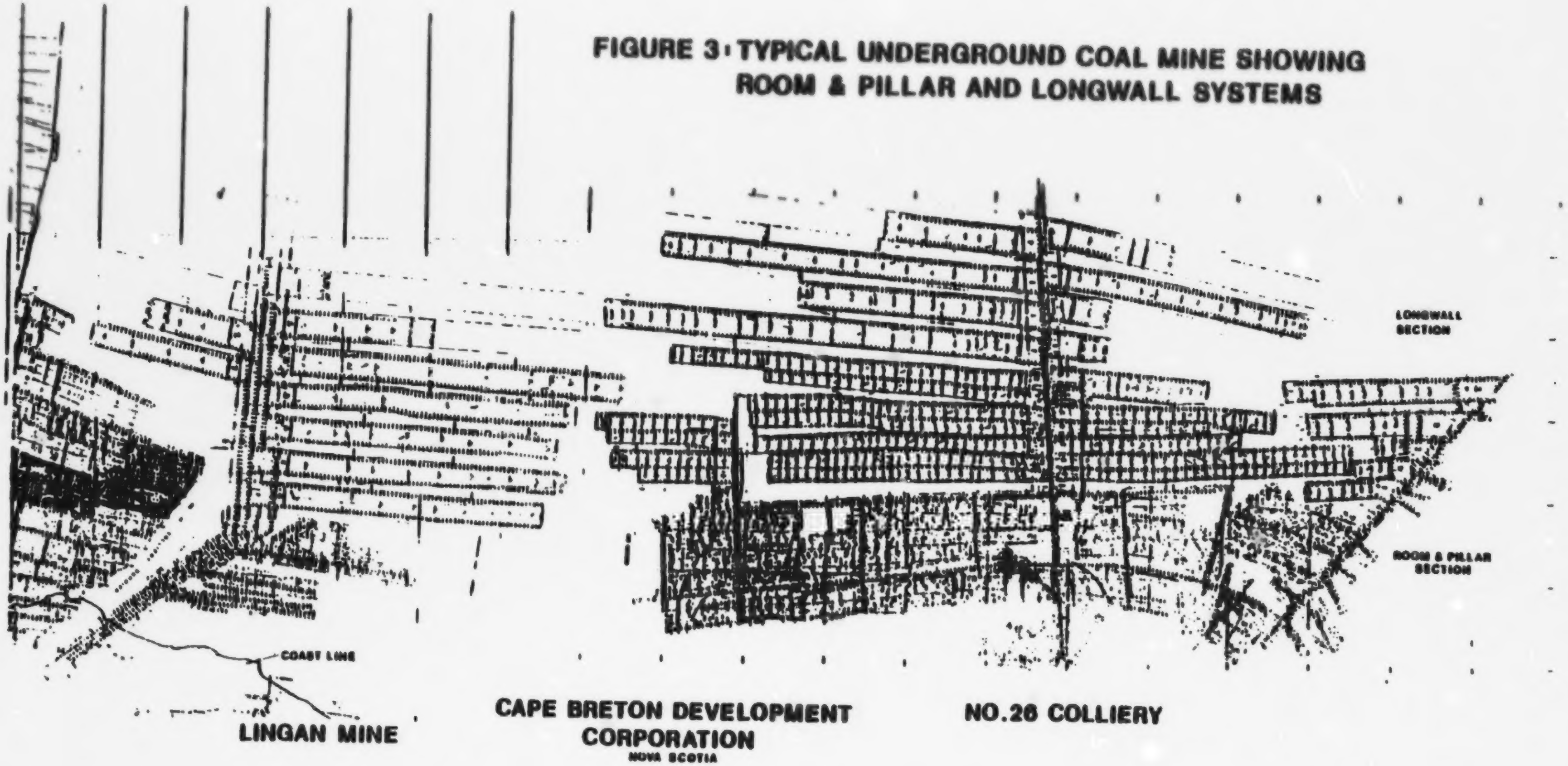
It must be appreciated that there are numerous variations and alternatives possible and indeed necessary to meet the many mining conditions found throughout the world.

Figure 3 illustrates the typical layout for an underground mine working both longwall and room and pillar system. These are for the Lingan and No. 26 mines of the Cape Breton Development Corporation in Nova Scotia, the only area where longwall mining is being practised in Canada.

3.2 OPERATIONAL CYCLE

As with most mining systems there are several operational modes. In this system, they are related to the timing of the movement of the roof supports after the coal cutting machine has passed that point on the face, and to the use of advancing or retreating mining systems.

FIGURE 3: TYPICAL UNDERGROUND COAL MINE SHOWING ROOM & PILLAR AND LONGWALL SYSTEMS


LONGWALL SECTION
ROOM & PILLAR SECTION
COAST LINE
LINGAN MINE
CAPE BRETON DEVELOPMENT CORPORATION
NOVA SCOTIA
NO.26 COLLIERY

The original practice, which is often called the "conventional" method simply calls for the face conveyor to be advanced immediately after the shearer has passed, and the roof supports advanced as close as possible to the working face immediately afterwards. This reduces the width of the immediate roof which has to be supported by the main roof supports. Unfortunately it also limits the area that is available for the work force to travel in or work in (Figure 4a).

An alternate is the "One web back" method where the roof supports are moved over to support the newly exposed roof immediately after the shearer has cut past but before the conveyor is advanced. This allows the work crews approximately 0.6 m more room to travel and work in and tends to aid productivity and in some instances working conditions (Figure 4b).

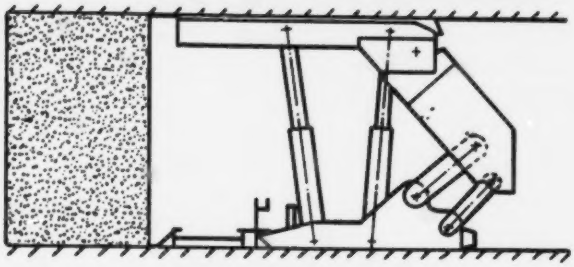
Bearing in mind the differences between these two methods, the basic cycle is: the coal getting machine(s) removes a slice of coal along the whole length of the face (either uni- or bi-directionally) loading the coal onto the face conveyor (AFC). The face conveyor is advanced by hydraulic rams, and the hydraulically powered roof supports lowered, advanced and reset one by one, following the advance of the conveyor in the first case, or afterwards in the alternate case. As the supports move, the roof behind them is allowed to cave (Figure 5).

4.0 WORLD USAGE AND BENEFITS

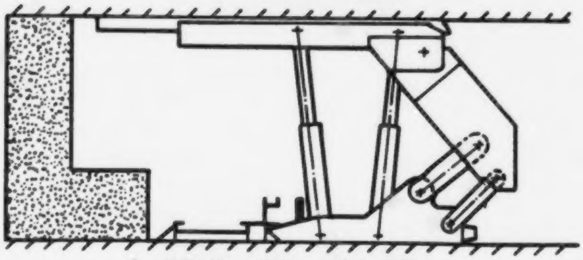
4.1 WORLD USAGE

The longwall mining system was developed in Wales in the early 1700's based on a 'hand got' mining system. The mechanised longwall face system dates from the late 40's and early 50's with the introduction

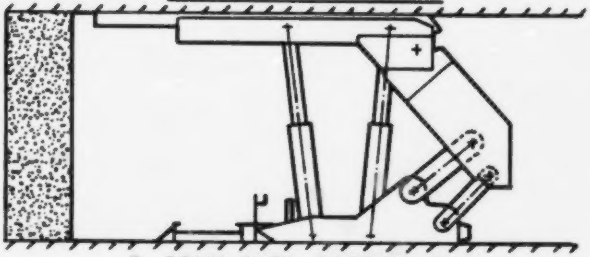
CONVENTIONAL MINING SYSTEM
CUTTING AND SUPPORT ADVANCE SEQUENCE



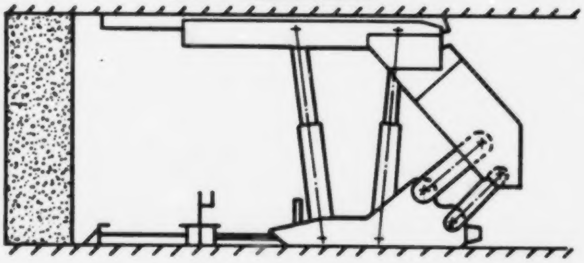
1. FACE BEFORE CUT



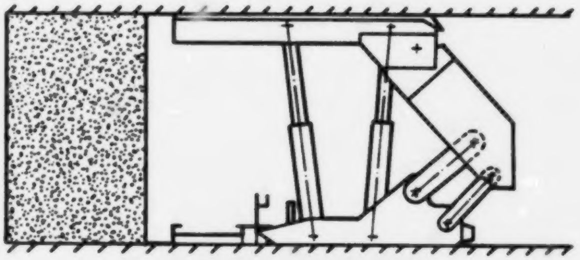
2. DRUM CUTS TOP COAL
CANTILEVER EXTENDED



3. DRUM CUTS BOTTOM COAL
ON RETURN RUN



4. CONVEYOR ADVANCED

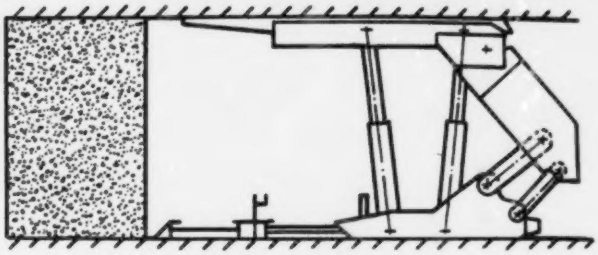


5. SUPPORT ADVANCED
CANTILEVER RETRACTED

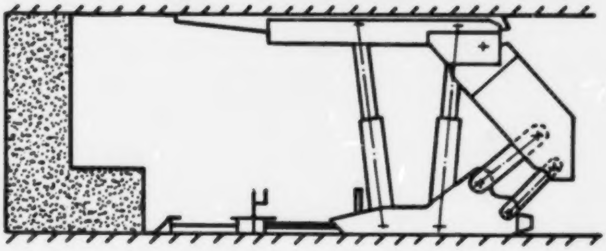
RECOMMENCE CYCLE AS IN 1

FIGURE 4a

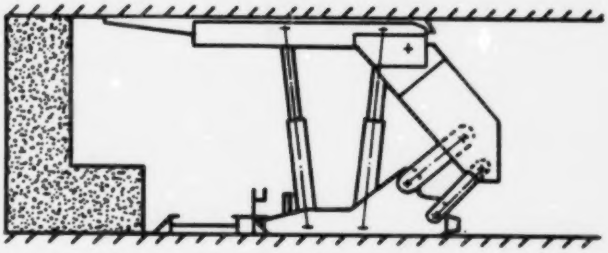
"ONE WEB BACK" MINING SYSTEM
CUTTING AND SUPPORT ADVANCE SEQUENCE



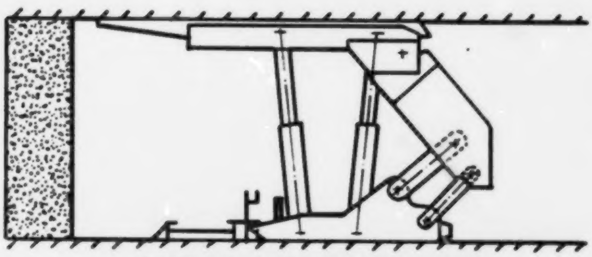
1. FACE BEFORE CUT



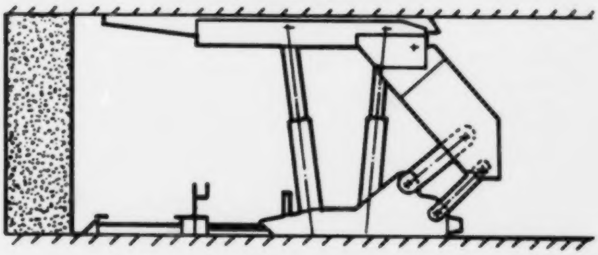
2. DRUM CUTS TOP COAL



3. SUPPORT ADVANCED



4. DRUM CUTS BOTTOM COAL
ON RETURN RUN



5. CONVEYOR ADVANCED

RECOMMENCE CYCLE AS IN 1

FIGURE 4b

TYPICAL CYCLES OF OPERATION FOR CONVENTIONAL AND "ONE WEB BACK" LONGWALL MINING SYSTEMS

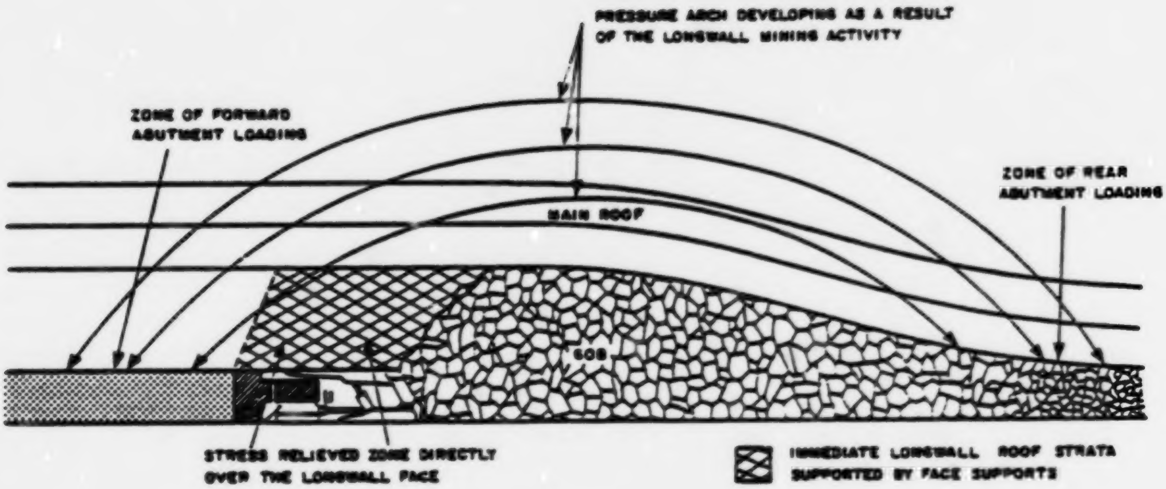

PRESSURE ARCH DEVELOPING AS A RESULT OF THE LONGWALL MINING ACTIVITY
ZONE OF FORWARD ABUTMENT LOADING
ZONE OF REAR ABUTMENT LOADING
MAIN ROOF
GOB
STRESS RELIEVED ZONE DIRECTLY OVER THE LONGWALL FACE
IMMEDIATE LONGWALL ROOF STRATA SUPPORTED BY FACE SUPPORTS

FIGURE - 5 : CROSS SECTION THROUGH AN ACTIVE LONGWALL PANEL of the plough and armoured face conveyor in Germany and the shearer in England, and in the mid-fifties, the hydraulic powered support also in England.

At the present time, the longwall mining system is in use in every major coal mining country in the world. Its predominant use, is naturally in those countries in which it evolved, namely U.K., W. Germany and France. The data given in Table II illustrates this.

TABLE II

LONGWALL MINING STATISTICS FOR MAJOR USE COUNTRIES

Country	Total Production Mt (1981)	% Output From Longwall	No. of Longwall Faces	LONGWALL FACES Av.Ht. (m)	Av. Face Length (m)	Av. Depth (m)
Canada	40	5	6	2.16	193	600
U.S.A.	700	8	112	1.78	168	350
U.K.	114	92	581	1.58	198	516
W. Germany	86	94*	247	1.82	223	850
Australia	92	4.5	8	3.11	140	210
France	22	47	104	3.18	160	680
S. Africa	130	8	11	2.86	182	145
China	576	37	n.a.	n.a.	n.a.	283

* 50% from shearers
50% from ploughs

It is interesting to note that in the countries where longwall mining is relatively new, the projected usage for the system is very good. For example, in the U.S.A. the number of longwall faces is expected to grow from 112 in 1981 to over 250 by 1985.

4.2 WHY LONGWALL?

As a mining system longwall mining has, compared with the room and pillar system, many advantages and also some disadvantages. These can be summarized as:

Advantages

(a) Safer environment - better protection from roof falls and haulage accidents.
- better and easier ventilation.

(b) Higher recovery of resources - between 60% and 80%.

(c) Higher production and productivity.

(d) More applicable for deep mining.

(e) Permits better control of strata in the mine and surface subsidence.

(f) More efficient for multi seam mining.

(g) Easier system to automate and monitor.

(h) Requires less development per tonne mined.

(i) Lower capital cost per tonne mined.

(j) Capable of mining coal in difficult mining conditions:

  - weak strata above and below the seam
  - seams disturbed by previous mining

- steeply pitching beds
- deep coal
- thin coal

(k) A high degree of concentration of working with beneficial impact on transport, ventilation, man-riding, power supply and management.

Disadvantages

(a) High initial capital costs.

(b) Face transfer problems. Lost time can be between four and six weeks so standby production facilities are often necessary.

(c) Transportation of heavy components requires special attention.

(d) Sensitive to panel development rates and coal clearance delays.

(e) More easily affected by geological disturbances.

5.0 MANPOWER, PRODUCTION & PRODUCTIVITY

In this section, an attempt is made to compare the manning levels, production and productivities and costs for longwall mining, room & pillar mining, and hydraulic mining. These figures vary considerably according to the method of mining, mine layout, etc. and must be treated with caution. Each and every mine has its own peculiar customs and conditions.

5.1 MANPOWER, PRODUCTION & PRODUCTIVITY

The manning levels given below cover the areas in the immediate vicinity of the working face, and take no account of personnel requirements outbye.

511 LONGWALL MINING

The typical requirement for a retreating longwall face working three consecutive shifts plus a maintenance shift will be:

Operation	Production Shifts 1	2	3	Maintenance Shift
Machine Operators	2	2	2	1
Roof Support Operators	3	3	3	-
Face End Workers	4	4	4	-
Mechanics	2	2	2	2
Electricians	1	1	1	2
Stage Loader Operator	1	1	1	-
Face Supervisor	2	2	2	1
	15	15	15	6
			TOTAL	51

This manning level is almost independent of face length and seam thickness. For longwall advancing faces, face end manpower has to be increased considerably.

512 ROOM & PILLAR MINING

The typical requirement for an eight entry panel system, using six continuous miners working three panels is:

	Production Shifts		Maintenance Shift
	1	2	
Miner Operators	12	12	-
Shuttle Car Operators	12	12	-
Rock Bolting Crew	12	12	-
Mechanics	2	2	6
Electricians	2	2	6
Foreman	3	3	1
	43	43	13
		TOTAL	99

513 HYDRAULIC MINING

The typical requirements for a hydraulic mine in steep seam conditions with two monitors operating continuously are:

	Production Shifts			
	1	2	3	4
Monitor Operators	8	8	8	8
Pull Back Crew	6	6	6	6
Mechanics*	1	1	1	1
Electricians*	1	1	1	1
Foreman	2	2	2	2
	18	18	18	18
			TOTAL	72

* Proportion of Electrical and Mechanical crew.

5.2 PRODUCTION LEVELS

As might be expected, production levels achieved vary tremendously from mine to mine and machine to machine.

The extremes of production are the world records which are set.

For room and pillar working, the record for a continuous miner is 131 100t in a month of 78 shifts operating in a 3.1 m seam. The shift average was 1 680t, the best shift 2 040t and the best day 5 230t.

For longwall mining, the record for a shearer is 210 652t in a month. This machine operating in a 3.0 metre seam in South Africa also produced 61 897t in one week, itself a world record exceeding the previous best by 10 000t.

For hydraulic mining, the record for a single monitor is 125,200t in a month of 22 days from a 16 m thick seam. Productivity for the total mine was 29.6t/MS.

A look at more realistic production levels is given in Figure 6 which shows average production (t/shift) for different seam heights. The curve for longwall faces is a composite average of operations in the United Kingdom, Canada and the U.S.A., whilst the curve for continuous miner is an average of room and pillar operations in the U.S.A. and Australia.

In general, a longwall face has a daily output of about five times that of a continuous miner, however in both systems output is very sensitive to seam height.

With the introduction and establishment of the new Heavy Duty and Advance Technology longwall mining systems in the U.K., experience is indicating that outputs from a 1.8 m seam of 1 000t/hour are now possible. This represents a considerable improvement on the general average of 1 100t/shift in this seam height.

In hydraulic mining, most operations are in thick seams, where outputs of 1500t to 2000t per shift per monitor are regularly achievable.

In the thinner seams (3-3.5 m) production is somewhat less, probably of the order of 1 000 to 1 100t/shift.

5.3 PRODUCTIVITY

In looking at the productivities of the various mining methods, a major problem arises because there is no common standard from country to country, or mine to mine for reporting figures.

Table III gives some average figures for the longwall operations in the countries listed. These must be compared with caution.

TABLE III

LONGWALL PRODUCTIVITY

Country	Typical Face OMS	Underground OMS
Canada	24.0(3)	5.60(3)
U.K. All Mines	-	2.53
New Mines	-	4 25(2)
All Faces	16.8	-
ATM Faces	29.3	-
West Germany	18.9	4.02
France	16.4	3.54
Australia	10.4(1)	n/a

(1) Longwall District OMS

(2) The forecast for all the new mines in the U.K. is for an average underground OMS of 10.6t when the projects are fully operational.

(3) For new retreating faces, figures are 40.0 (Face) and 7.0.

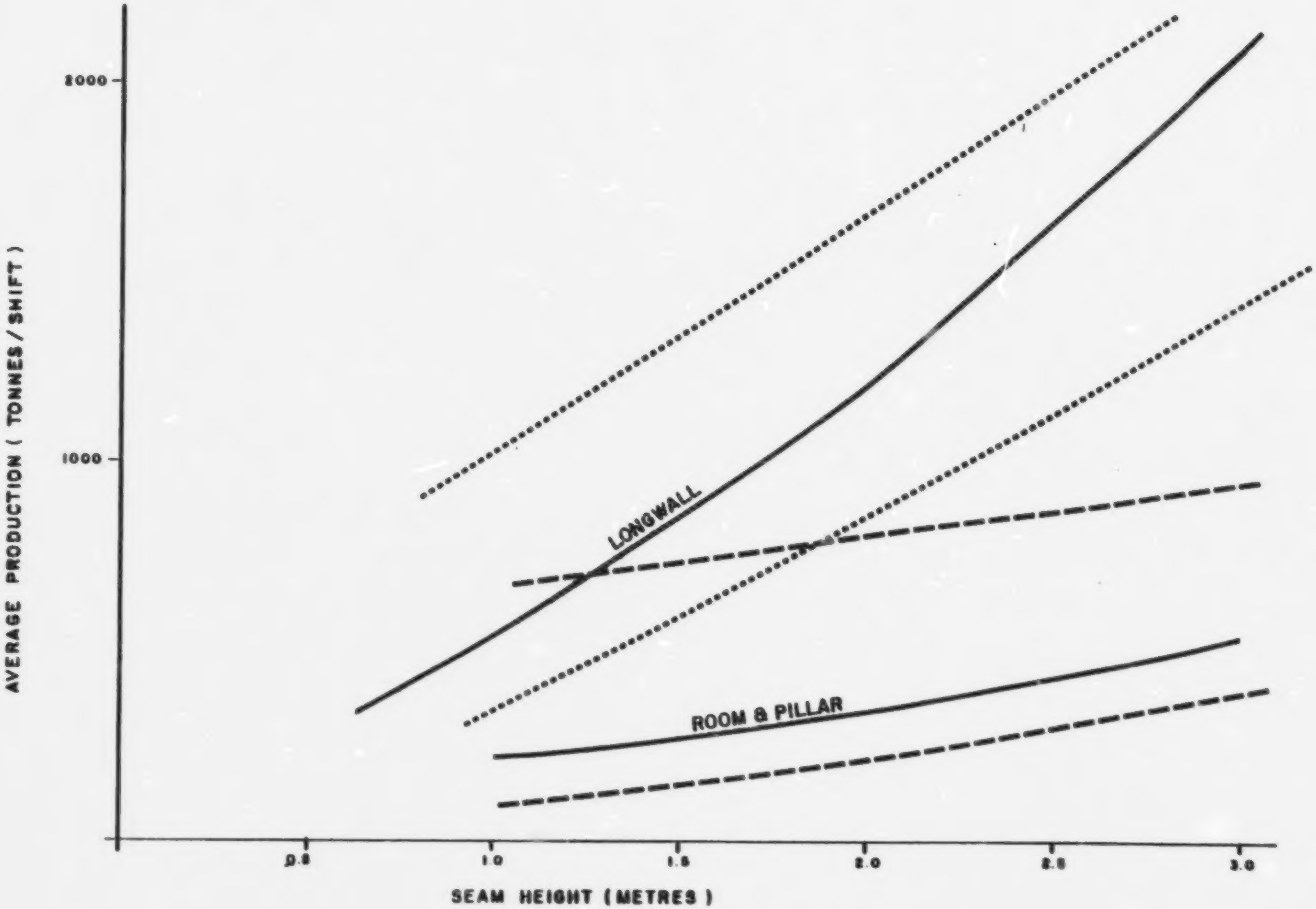


FIGURE – 6 : RANGE IN AVERAGE OUTPUTS FOR LONGWALL AND ROOM & PILLAR FACES AT VARYING SEAM HEIGHTS

In room and pillar mining, face productivities are generally lower than those for longwall mining, ranging from 8 to 12 tonnes per manshift, whereas in hydraulic mining the productivity ranges from 50 to 200 tonnes per manshift.

5.4 COSTS

Both capital and operating costs vary appreciably according to the specific conditions at each mine site and operation. Figure 7a shows how the capital cost of a longwall face varies with both seam height and output whilst Figure 7b shows how cost per tonne and return on investment vary with face length.

The capital cost of a longwall face is dependent on seam height and face length since variations in these factors have a significant effect on the size and number of face supports required. The face supports form the major item of capital expenditure. For a typical longwall system with a face length of the order of 180 m and in a seam of 3 metres height, capital expenditure to equip the face including stage loader and electrics will be between 12 and 15 million Canadian dollars.

Perhaps the most pertinent comparison which can be made is to examine Table IV. This gives capital and operating cost estimates for longwall, room and pillar and hydraulic mining for similar outputs from similar seam thicknesses.

The basic parameters are:

(i) Longwall System

One longwall face plus two continuous miners for development working in 3.4 m seam.

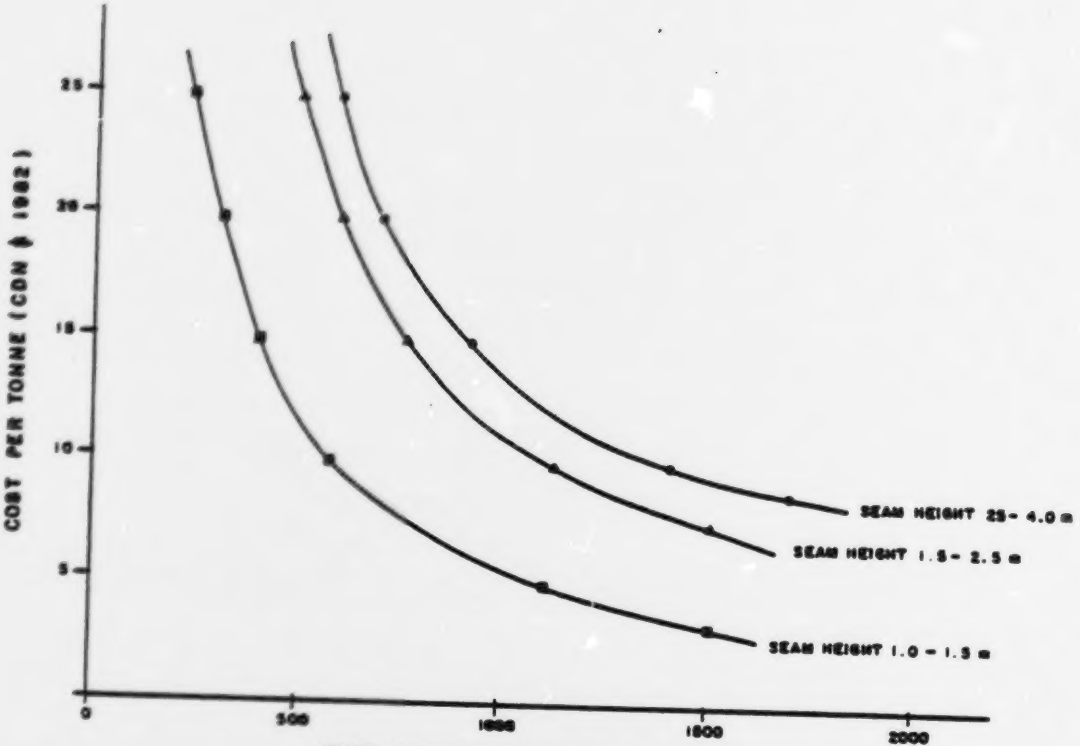


FIGURE - 7a: CAPITAL EQUIPMENT COST PER TONNE vs. OUTPUT AND SEAM HEIGHT

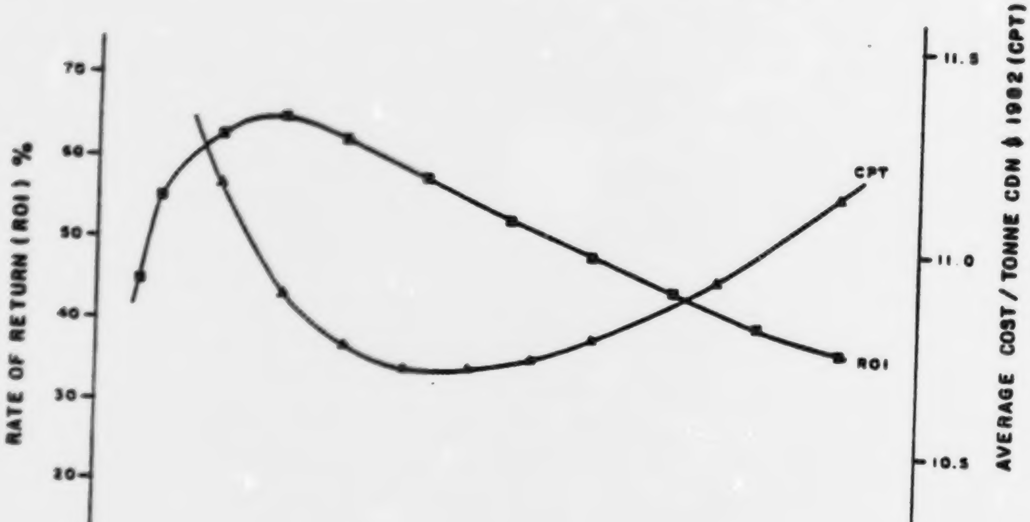


FIGURE - 7b: COST PER TONNE AND RETURN ON INVESTMENT vs. FACE LENGTH

(ii) Room & Pillar

Six continuous miners for development and depillaring in a 3.0 m seam.

(iii) Hydraulic Mining

Two monitors working continuously (12 in total) with five heading machines for development in a 3.5 m seam.

TABLE IV

Capital and Operating Costs (US$)

Output per year (Raw Case)	1.8Mt	2.0Mt	2.6Mt
Operating Costs/year	$26.6M	$38.8M	$17.9M
Capital Expenditure	$21.0M(1)	$18.2M(1)	$14.1M(2)

(1) Mining and Transportation Equipment only.

(2) Gravity drainage only.

6.0 CONCLUSIONS

This brief comparison of the two main underground coal mining systems shows that longwall mining offers considerable advantages over room and pillar mining especially in the areas of production, productivity, manning levels and operating costs. When hydraulic mining is considered, it is the most attractive particularly where gravity drainage can be used. Unfortunately, as this system is in limited use, a clear and precise comparison cannot be made.

The answer, therefore, to the question "Why Longwall" is evident. In the right circumstances and conditions, longwall is safer, more resource efficient, more productive and cost efficient than Room & Pillar mining. Experience and facts prove it.

GEOLOGIC AND GEOTECHNICAL CONSIDERATIONS FOR LONGWALL MINING

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Norwest Resource Consultants Ltd., Calgary, Alberta CANADA

ABSTRACT

Geological and geotechnical interpretations are processes of prediction based on data from specific locations. Their quality is based on the collection of accurate data, and the selection of relevant models. Longwall mining often requires high capital investment and is particularly sensitive to variations of geology, so great accuracy is required in geologic interpretation. Longwall mining studies such as those by McIntyre Mines should be considered to be the required norm rather than extraordinary in-depth investigations; other mining methods could equally benefit from that level of geological and geotechnical detail. There are many examples where productivity, financial performance and safety have been jeopardized by inadequate initial geologic and geotechnical studies.

Geological factors that effect longwall mining are of two types: sedimentological and structural. Sedimentological factors include correlation, seam descriptions, and descriptions of roof and floor strata. Structural factors include descriptions of observed structures such as those normally presented on cross-sections and structure contour maps, and structural analysis documenting characteristics such as joints, cleats and other small-scale features. It is essential that the geologist convey the significance of those factors to the mining engineer; hazard analysis can provide a semiquantitative expression of the net impact of the geological factors.

Geotechnical factors that affect longwall mining include material strengths, state of stress, hydrology, and methane content. The study of these factors affects the specific design of roof supports, specifications for the dimensions of the longwall face and pillars, ventilation requirements, and the control of water.

INTRODUCTION

Geological and geotechnical studies are a process of prediction based on data from specific locations. Engineers are interested in all of the materials that lie between those data-points, but geologists cannot directly observe that material prior to extraction. Thus, "geological interpretations" can be colloquially described as "a guess". This guess may be an accurate one or an inaccurate one, or indeed, any possibility in between. However, a mining engineer expects the geologist to make accurate and precise guesses; the nature of longwall mining requires the highest possible level of precision and accuracy in its geological guesses.

At their disposal, geologists and geotechnical engineers have a variety of samples from specific locations, from which they develop data. They also have theoretical and empirical models from various branches of the earth sciences, that are derived from well-documented case-histories. The process of geological interpretation is the integration of the data with appropriately selected models. Therefore, the quality of the interpretation is dependent upon two factors: the selection of relevant models, and the collection of accurate data.

All too often, budget constraints do not allow geological and geotechnical studies to be made with sufficient accuracy to reduce the financial risk of mining to an acceptable level. From a geologist's or geotechnical engineer's point of view, longwall mining studies such as those recently completed by McIntyre Mines should be considered to be a required acceptable norm, rather than an extraordinary in-depth investigation.

GEOLOGICAL CONSIDERATIONS FOR LONGWALL MINING

Geological studies provide descriptions of the materials to be mined, and the surrounding materials that must be addressed in mine planning and controlled in a mining operation; these studies are both quantitative and qualitative in nature. Geotechnical studies provide quantitative documentation of the geological descriptions.

From a geologist's point of view, longwall mining is no different from any other underground mining method; longwall mining is simply a specific process of pillar extraction. However, when longwall mining is being planned, a geologist is often call upon to document the geology to a level of detail greater than that required where other forms of mining are anticipated. This occurs for two reasons:

a) Longwall mining is particularly sensitive to variations of geology; this means that unforeseen geological features such as small-scale faults and rolls of the floor tend to have a greater impact on mining activity.

b) The establishment of a longwall mining system often involves a high capital investment; the financial risks for this capital investment are directly related to the reliability of the geologic interpretations.

Thus the differences between longwall mining and other underground mining methods are more related to engineering and financial considerations than to geological ones.

Other mining methods could equally benefit from the level of geological detail usually required for a longwall mining study. The decision to limit geological exploration has often been based, to a large extent, on the belief that the chosen mining system is flexible enough to cope with any unforeseen geological situations. While this assumption is sometimes correct, there are many examples where productivity, financial performance, and even the safety of mining personnel, have been jeopardized.

TABLE 1

GEOLOGICAL CONSIDERATIONS FOR LONGWALL MINING

1. Sedimentological Factors
    - correlation
    - seam descriptions
    - roof and floor descriptions

2. Structural Factors
    - structural descriptions
    - structural analysis

3. Hazard Analysis

TABLE 2

GEOTECHNICAL CONSIDERATIONS FOR LONGWALL MINING

1. Surface Exploration Programs
2. In-Mine Instrumentation Programs
3. Subsidence Studies
4. Gas Emission Considerations
5. Hydrogeologic Studies

Table No. 1 lists most of the more important geological factors that affect longwall mining. The following is a discussion of each of those elements.

Sedimentological Factors

Correlation

The thickness and continuity of a seam have a major impact on the selection of mining equipment and productivity of the mine. During the planning phase of a longwall mining operation, the thickness is usually interpreted from coal seam sections measured in boreholes and surface exposures. In these circumstances, the measurements are obviously not continuous from one data-point to the next, and it is therefore necessary to make a subjective judgement about the nature of the seam or rock bed in between those points.

When using surface and drillhole data alone, the continuity of seams and associated strata is interpreted on the basis of the degree of similarity between geological data from different locations, and on the basis of the environment of deposition of the material. This interpretation cannot be made until a correlation has been completed; for any type of coal mining, the correlation for individual seam elements is extremely important. In some cases the correlation of seams and the small units within them is not a particularly difficult problem; however, there are many examples where correlation is indeed difficult due to the number of seams, the variation of the characteristics of individual seams from place to place, and the lack of characteristic variation of the surrounding materials.

It must be clearly understood that concept of correlation implies neither constancy of thickness of beds, nor regular variation of thickness. The author has observed that many interpretations of correlation have been unduly influenced by extreme examples of either variation or constancy of thicknesses, factors that are only important judging the reliability of the interpretation.

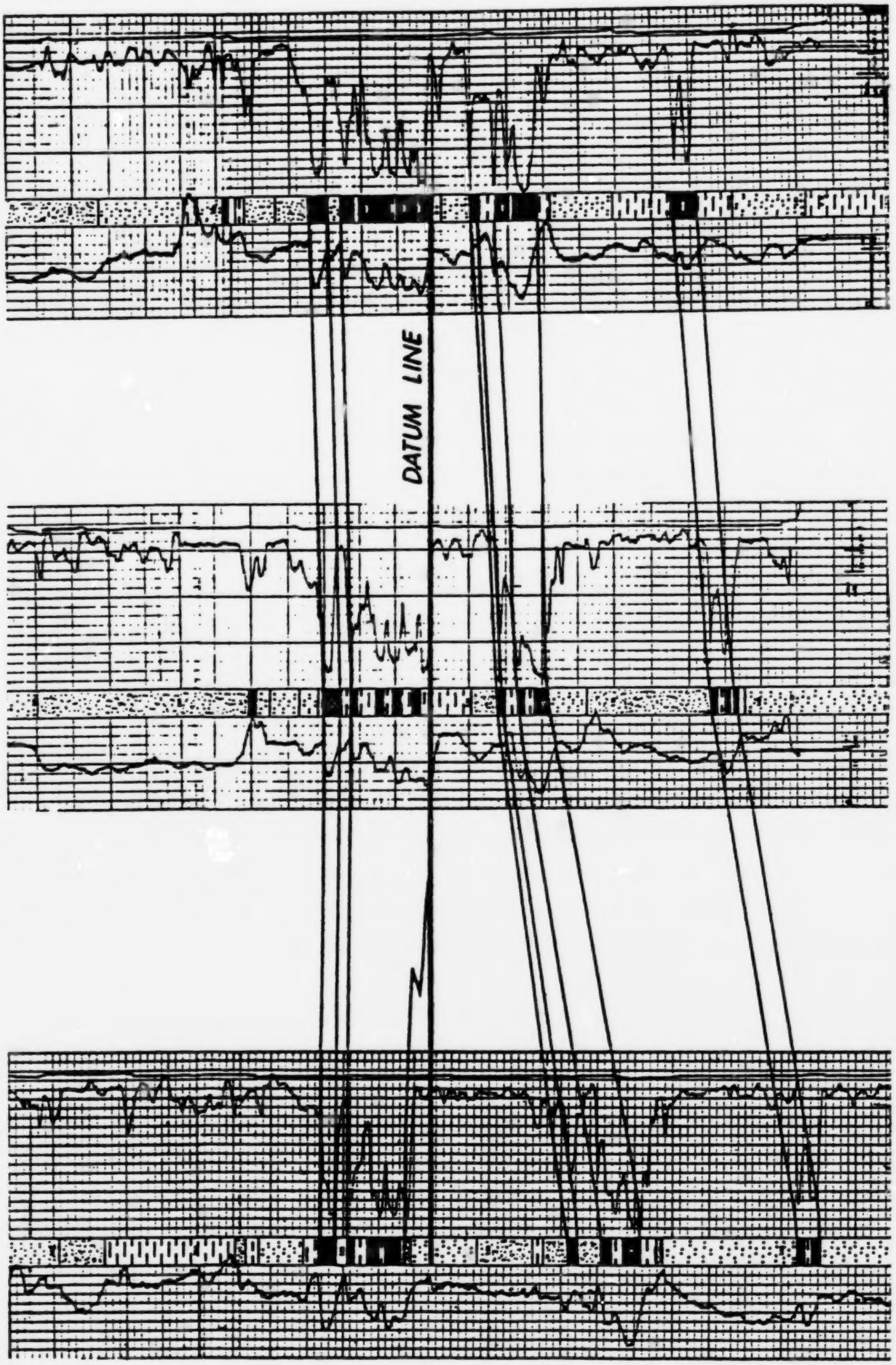
The author encourages the use of borehole geophysical logs both for the interpretation of correlation, and for the presentation of that interpretation (Figure 1). The borehole geophysical logs are not complicated by natural differences in drafting style as are hand-drawn stratigraphic sections. The geophysical logs usually provide a more easily observed and more detailed pattern of variations than can be drawn by hand from lithologic descriptions.

Seam Descriptions

Seam descriptions are the documentation of all of the changes in the physical nature of the seam materials as observed at data-points, followed by the prediction, at an equal level of detail, of the physcial character of the seam materials between the data-points. The samples from the data-points are such things as cores, logs and surface exposures. The more thorough the understanding of the materials at the data-points, the greater the chance of developing reliable predictions between the data-points. Detailed logging of all changes is therefore an important consideration; a log of a seam described only as "coal" from the roof to the floor, provides little opportunity to accurately deduce the variation of that material away from the data-point (Figure 2).

It is also important to fully evaluate factors that are anomalous and unrelated to a normal stratigraphic situation. These factors could include errors recorded by drillers, assistants, field geologists or others; loss of core during drilling; the effects of surface creep and slumped blocks on coal exposures; the effect of borehole conditions on geophysical logs; and a wide range of similar occurrences.

Interpretation of the continuity of variability of seams and rock bands between data-points is essentially subjective and is based on an geologist's past experience with the probability of intersecting a particular seam at a predicted point, the variability of the geology within a particular environment of deposition, the similarity of the



A CORRELATION USING CORE & GEOPHYSICAL LOGS

FIGURE 1

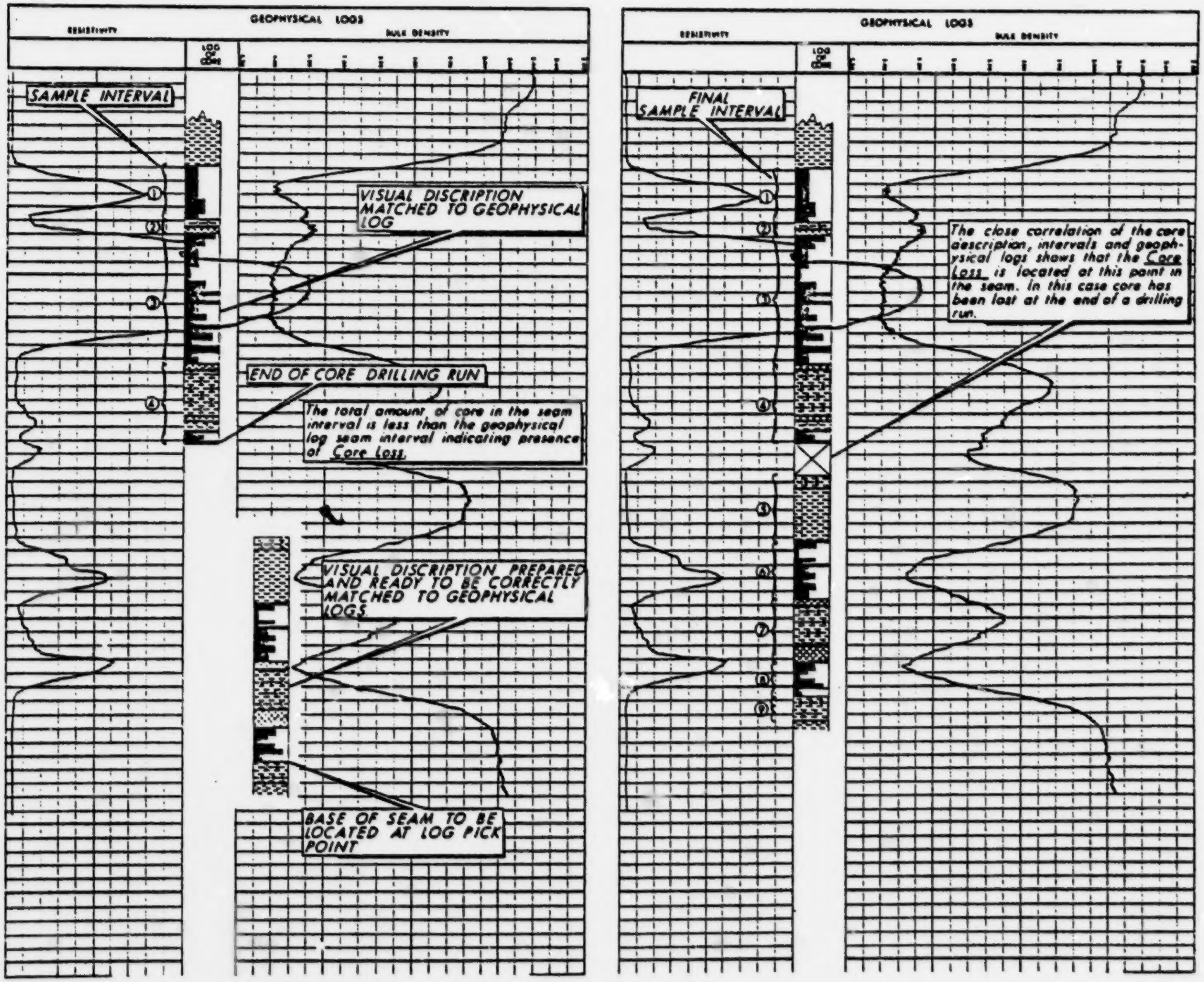


FIGURE 2

DESCRIPTIONS USING CORE & GEOPHYSICAL LOGS geology at two separate locations, and observations of the rate of variation of thickness in natural or man-made continuous exposures.

Once the interpretation has been made that a seam is continuous within a given area, isopach maps are prepared to illustrate its variations of thickness. These maps are usually prepared using rigorous arithmatic models; subjective modifications can be made where unusual thickness variations are suspected between data-points, such as projections of localized zones of tectonically thickened coal.

Accurate isopach maps are particularly important where the mining of seams less than 2 m thick is planned. Studies in the U.S. have indicated that productivity decreases with diminishing seam thickness, particularly for seams less than 2 m thick. In part, this is caused by requirement to work in area with less than standing height. The percentage of out-of-seam dilution also increases in thin seams, due to a tendency to gather rock material from the roof or floor of the seam.

Isopach maps of rock bands within the mining section of the seam should also be prepared wherever possible. In most cases the bands are considerably harder than the coal and slow the rate of mining advance. In the relatively rare instances where the rock band material is soft clay, the rate of advance is also reduced, with the clay tending to stick to and foul the picks of the cutting equipment. Thus, in any case, as the thickness of rock bands increases, production decreases.

Rock bands up to .3 m thick are usually mined with the coal. Where their thickness is greater, it is common to attempt to avoid the rock by mining either on top of the band or below it. In some cases it is possible to mine the lower coal split separately, using the rock band material as a roof. In special circumstances, rock bands up to about .5 m thick may be mined with the coal, but usually only over relatively short distances to gain access from one mining area to another.

It is not always possible to demonstrate a correlation of rock bands in a single seam between data-points. In these circumstances, it is still possible to present geological data in form suitable for engineering purposes; this is done on a statistical basis. A map showing the data-points can be prepared showing the number and thickness of the individual rock bands, the total thickness of the seam, and the number of thickness of individual coal splits.

Roof and Floor Descriptions

The first 3 m to 5 m of strata forming the floor of each seam that is a potential target for mining, should the subject of particularly close inspection. These inspections begin with core logging and continue through to the presentation of data. During core logging, these features at least should be described:

a) Lithology
b) The nature of change from one lithology to the next
c) The degree to which bedding is developed
d) The nature of bedding
e) The presence of bioturbation and the extent of its development
f) The presence of natural fractures
g) Fracture frequency
h) The nature of fracture surfaces
i) The inclusion of secondary mineralizaiton on natural fractures
j) Classification of fractures
k) Qualitative judgement of rock strength
l) Core state
m) Apparent dip of bedding and fractures

Any lithologies with a high constract in mechanical properties, must be identified and described, particularly soft units such as thin coal seams or soft clay zones. The presence of expanding clays in the floor and roof is a particularly difficult and potentially dangerous circumstance, and testing to determine the chemistry of the clays in the sequence affected by mining is usually justified.

Excluding geotechnical testing, the best data available for the documentation of floor conditions are:

a) Written core description
b) Detailed geophysical logs
c) Core photographs

Hand-drawn stratigraphic columns are quite often used to illustrate floor conditions, usually in combination with the correlation of coal seams. It is difficult, however, to show the necessary detail on stratigraphic columns. The documentation of core through photography and the manipulation of the photographs as an interpretive tool is a relatively recent introduction into commercial exploration projects. In the past photographs taken essentially for record purposes only. However, with photographs available, an elegant chart indicating floor conditions can be prepared by splicing photographed core sections of the floor into a chart that illustrates seam correlation.

Much of the discussion of floor strata equally applies to the roof. The interval in the roof of each potentially mineable seam that should be subject to close inspection is at least 6 m, and can be as much as 15 m where hazardous conditions such as intensive fracturing, swelling clay beds or massive sandstone units are present. The presentation of data for roof conditions can follow the same procedures adopted for the documentation of floor conditions.

Plans for longwall mining require that special considerations be given to preparation of detailed descriptions and isopach maps where massive, strong units occur in close proximity to the seam roof. Where these units are thicker than 3 m and and lie within 15 m of the seam roof, isopach maps of both the massive unit and the interval between the top of the seam and the base of the massive unit should be prepared, because of potential cantilevering problems associated with the caving of this material as mining proceeds.

Structural Factors

The requirements of structural geology for engineering fall into two broad categories:

a) Structural descriptions by structure contour maps and cross-sections illustrating the gross nature of the geometry of the body to be mined.

b) Structural analysis detailing orientations and frequencies of small-scale features that can be a benefit or an impediment to the mining operations and product quality; these features may also have a direct bearing on the safety of underground workers.

Structural Descriptions

Structure contour maps are used to describe the geologic structure of an area. These maps, combined with isopach maps, are the primary documents upon which mine layout, panel development, access consideration and mineable reserves are planned. Consequently, structure contour maps are usually produced for each of the mineable coal seams. Normally this involves the production of three or four maps.

The structure of the seams cannot be contoured until an appropriate seam correlation has been proposed. The most effective method for preparing structure contour maps,in the author's experience, is to prepare a series of parallel cross-sections spaced at equal intervals, and to project drillhole and other data onto these sections. The data should include the elevation, of drilled intersections, outcrops, and the projection of seam positions on the cross-sections.

One contour map for a seam towards the centre of the stratigraphic section can be prepared in this manner. Unexplained irregularities in its contours will identify inconsistenies in the interpretation on the cross-sections. Once those irregularities have been corrected on the contour map, the cross-sections should be modified to be consistant.

Another structure contour map is then prepared, on the roof or floor of a second mineable seam, either higher or lower in the section. Irregularities in the contours are again used to identify and correct specific problems in the interpretation on the cross-sections. This process continues until map has been prepared for each mineable seam and the cross-sections have been adjusted so that the structural interpretation is consistent in a three-dimensional sense from the top of the sequence to the base, as well as laterally with respect to known data-points and the cross-sections. Maps of other surfaces can then be prepared as required. It is worth noting that, once this procedure is completed, even small changes or either the cross-sections or structure contour maps requires an equivalent modification of every other interpretation element if the description of the structural geology is to remain consistent.

Sometimes it is useful to prepare contour maps of nonvertical fault planes prior to preparing seam contours. These fault contours allow the limits of a faulted block to be projected at the intersection of equal seam and fault contour values. Contour maps should also show zones of seam overlap which occur with thrust-faulting, or missing seam zones which occur with inclined normal faults; the limits of these zones can again be projected from the intersections of seam and fault contours.

Structural Analysis

Mine planning and operations are strongly affected by the attitude and limits of the body to be mined, and by the extent to which that body and the surrounding strata are broken by natural fractures. The attitude and limits of the body are illustrated by structure contour maps, while the nature of fractures is best demonstrated by structural analysis. The techniques of structural analysis also allow reasonable prediction of frequencies and orientations of fractures between data-points, as well determination of the nature of the stress field that caused those structures.

The elements of structural geology that are usually of most significance to structural analysis for mining purposes are:

a) coal cleat
b) joints
c) small-scale faults
d) zones of shearing
e) small-scale folding

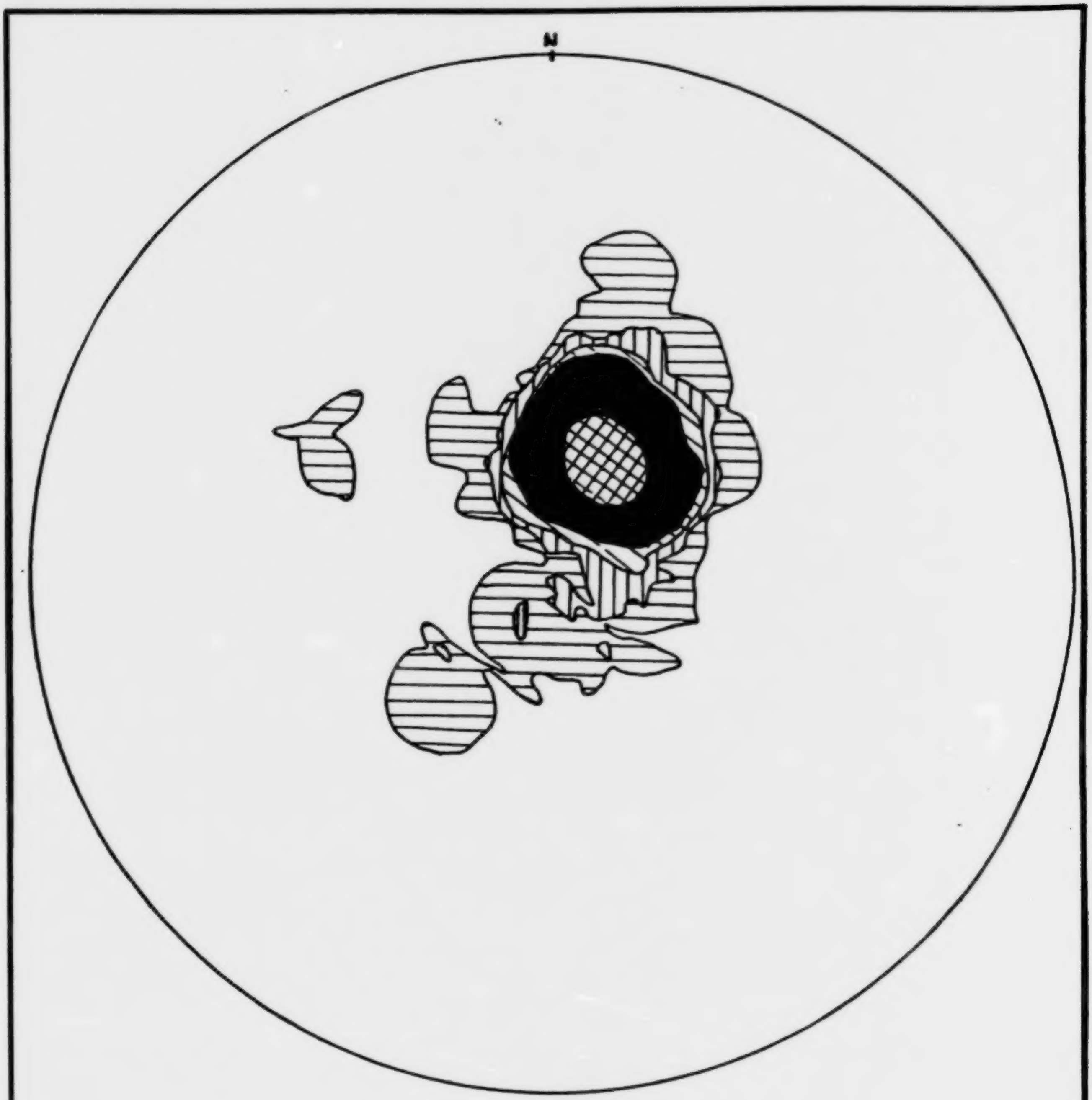
The stratigraphic frequency and orientation of these features with respect to various seam locations and attitudes is the major concern. A typical study begins with the documentation of all known occurrences structures such as stone rolls, small folds, small-scale faults and shear zones. Data on structures such as joints, cleats and slickensided surfaces are collected from sites that are chosen to be representative of a range of bedding orientations, as well as to provide lateral coverage in the area planned for mining. This information is then studied on a statistical basis using stereograms (Figure 3).

The annotated, contoured steroplots, and block-diagrams illustrating the average orientations of planes, are then included with the descriptions of the structural features in a report (Figure 4 and 5).

Hazard Analysis

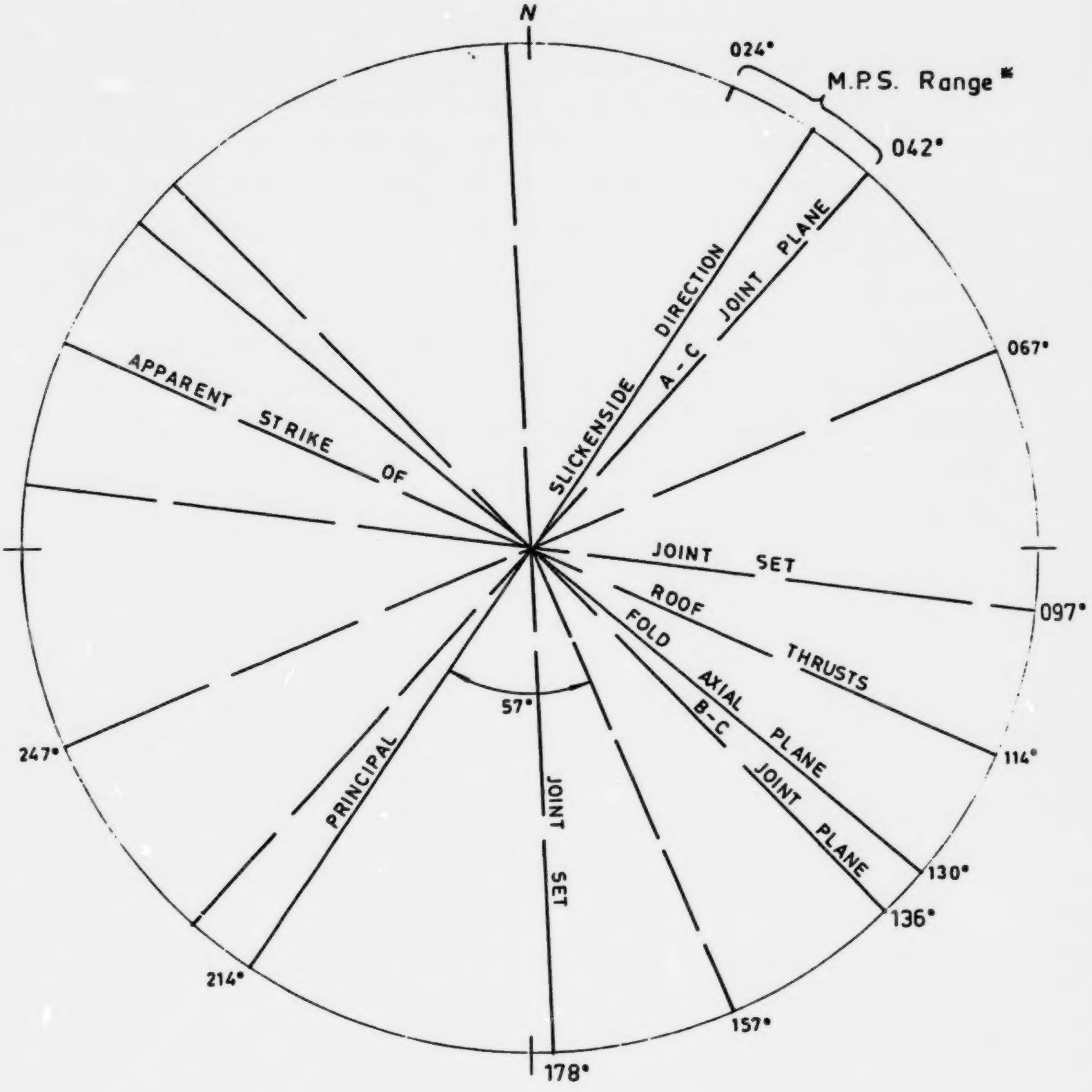
The study of geology usually involves the separate description of various categories of naturally occurring features. Engineering involves the study of the net effect of all of these features, as they have an impact on each other.

Hazard analysis is one means by which geologists can demonstrate to engineers the total effect of the various elements of the geology. The procedure is



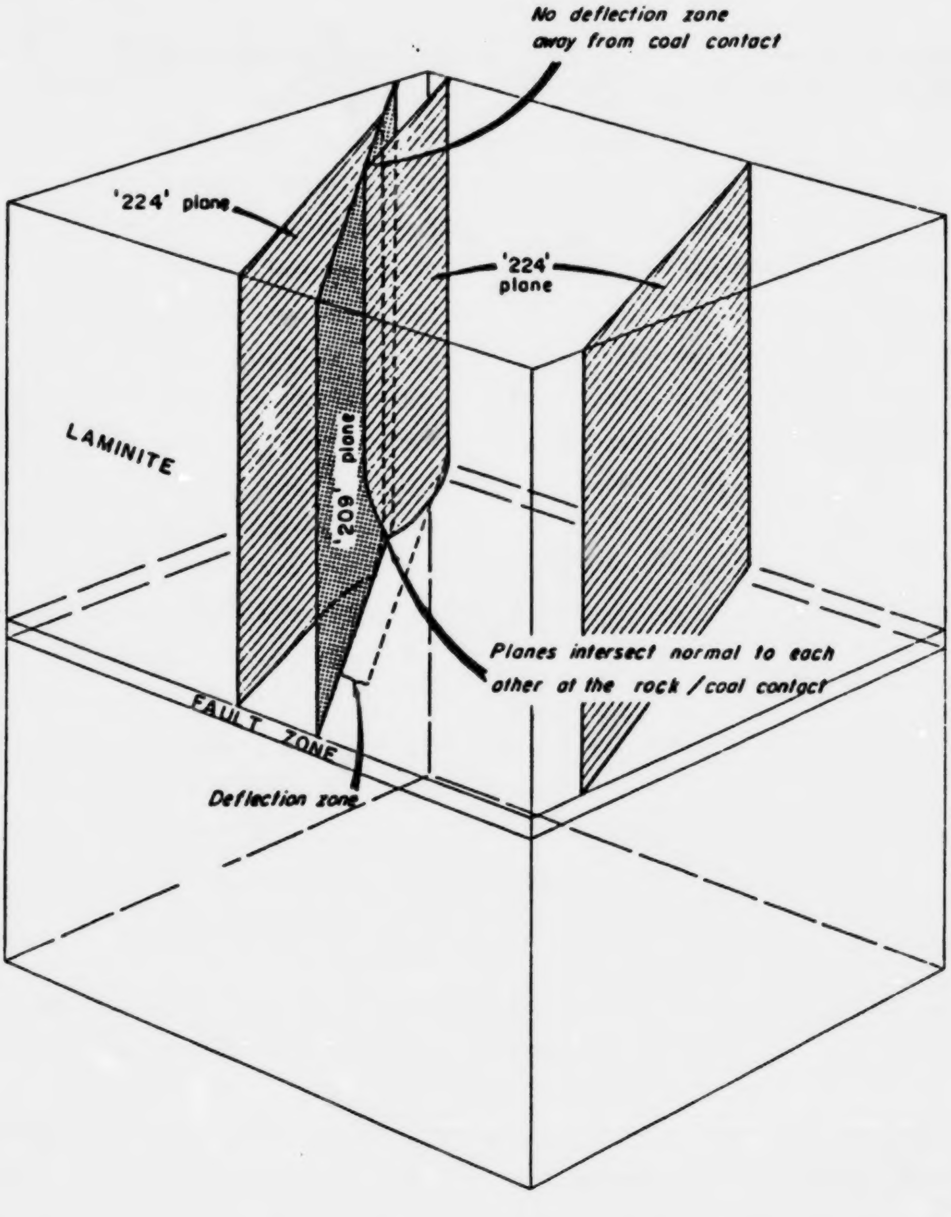
STEREOGRAMS TO PRESENT STRUCTURAL ANALYSIS DATA

FIGURE 3


N
024°
M.P.S. Range *
042°
SLICKENSIDE DIRECTION
A - C JOINT PLANE
067°
APPARENT STRIKE OF
PRINCIPAL
JOINT SET
097°
ROOF THRUSTS
114°
FOLD AXIAL PLANE
130°
B - C JOINT PLANE
136°
57°
JOINT SET
157°
178°
214°
247°

GENERALISED DIAGRAM OF
STRUCTURAL ELEMENT DIRECTIONS

FIGURE 4



No deflection zone away from coal contact
'224' plane
'224' plane
LAMINITE
'209' plane
Planes intersect normal to each other at the rock / coal contact
FAULT ZONE
Deflection zone

Block diagram showing relationship between joint planes

FIGURE 5

to determine from engineers where their major concerns are expected to lie in each particular mining case, then to prepare simplified maps showing these features, and to overlay each of these to prepare a combined map. Usually arbitrary and subjective values are assigned to each map element to indicate relative differences in the particular condition; judgements of "good", "average", and "poor" are common and values of "1", "2", and "3" are often assigned.

A typical case might include a map for seam dip; appropriate categories could be 0^o to 10^o, 10^o to 20^o, and over 20^o. Another map might show the degree of rotation of the strata; categories might include rotation through 20^o over distances of less than 100 m, rotation through 20^o over distances of 100 m to 500 m, and rotation through 20^o for distances greater than 500 m. Other parameters that could be mapped include:

a) Fault frequency
b) Fault displacement
c) Joint frequency
d) Roof lithology
e) Floor lithology
f) Variation in seam thickness
g) Reliability of correlation

These individual maps are overlain to produce a combined map showing a series of relatively small irregular blocks. The total of the numerical values for each block is calculated on this map, and an appropriate shading scheme chosen to highlight these values.

Geotechnical Considerations for Longwall Mining

Geotechnical studies for mining engineering fall into two broad categories:

a) Laboratory testing and field investigations from surface exploration programs. This type of study usually involves mainly the sampling and testing of drill cores, and can be supplemented with observations of surface exposures and indirect surveying techniques such as borehole geophysics. These studies are usually closely interfaced with the activities of exploration geologists, whose studies proceed at the same time.

b) In-mine instrumentation programs. The opportunity to conduct such a program exists when a mine is contemplating expansion, or a change in the type of mining. An instrumentation program may also be introduced into an existing mine with a view to studying the performance of current mining; the knowledge gained allows changes to be made to improve productivity, efficiency and safety.

The objectives of both surface programs and in-mine instrumentation programs are to evaluate or determine:

a) mining equipment design parameters
b) mine layout parameters
c) material caving characteristics and subsidence effects
d) gas emission problems
e) water problems

At all times the overriding consideration is to provide a stable and safe working environment for the underground mining personnel.

In-mine instrumentation programs provide data more closely related to an actual mining operation than that from surface exploration. Ease of access and continuity of exposure allow more data to be collected and the results to be more reliable. Therefore, there is more confidence placed in the results of in-mine instrumentation programs than in surface exploration programs.

Geotechnical exploration, conducted either from surface or underground, normally includes separate programs to investigate features of the rock mass, hydrogeology, and gas phenomena. Studies of subsidence may be incorporated with studies of the rock mass, or conducted separately.

Surface and in-mine studies of the rock mass usually address equipment design parameters and mine layout parameters. Equipment design parameters include such items as:

a) bearing capacities of floor materials
b) caving height
c) caving characteristics
d) bulk density of caving material
e) support load densities

These items are required as primary input for the design and manufacture of an underground support system, particularly for the design of longwall supports and for the prediction of performance of longwall supports in particular mining situations.

Mine layout parameters include such items as:

a) pillar dimensions
b) roadway dimensions
c) face length
d) mining orientation

Clearly there is a close link between the geotechnical evaluation of these parameters and mine plan engineering. The study of these parameters is usually based on theoretical models of the rock mass supported by actual site-specific data. In most cases there are a variety of models to chose from when addressing any mine design problem, and the assumptions built into the different models can vary significantly. The best results can be expected from theoretical models that most closely approximate the real situation, that incorporate details of as many geological variables as possible and that allow the input of the maximum amount of accurate, site-specific field data. Even with the most suitable models, however, it is difficult to judge how reliable the mine design criteria will be when implemented.

Surface Exploration Programs

Geotechnical studies resulting from surface exploration usually involve geotechnical logging of cores and laboratory testing of materials.

Typically, geotechnical core logs include descriptions of:

a) Core recovery
b) Rock quality designation
c) Fracture description
d) Fracture intersection angle
e) Fault zones
f) Hardness
g) Weak and strong zones
h) Partings

The results of these logs are normally presented as both graphic and written descriptions in a form similar to the logs prepared by geologists.

Typical laboratory tests of roof, coal and floor materials might include:

a) Unconfined compressive strength
b) Direct shear strength
c) Triaxial testing
d) Bulk density tests

The unconfined compressive strength, usually one of the most common physical properties cited, is determined by placing rock cores having a length-to-diameter ratio of approximately 2:1 or greater in a standard testing machine and loading the core to failure. The tangent modulus (elastic modulus) can be determined if the axial displacement is recorded during the test. The direct shear test is conducted to determine the apparent friction angle and cohesion of the material being tested. These two variables when combined define the shear strength of the rock or material. The triaxial test is a much more sophisticated, flexible and time-consuming test than the direct shear test. Interpretation of the results is similar to the direct shear: the cohesion and friction angle are obtained for the rock mass to determine its shear strength. Bulk density is a simple test in which the mass and volume of the sample are measured.

In-Mine Instrumentation Programs

An in-mine instrumentation program is designed to measure the actual performance of a mine structure (i.e. pillar, entry, longwall support, etc.). Specifically, the program should accomplish the following:

a) Provide a description of the geologic setting of the instrumentation area, including descriptions of near-seam stratigraphy and descriptions of all faulting, jointing, cleat and any other major geologic discontinuities.
b) Provide pertinent physical properties for the coal and adjacent roof and floor rock strata.
c) Determine the rock mass response to mining with emphasis on monitoring changes in the stress field.
d) Determine the distribution of stress change in the pillars.
e) Determine the distribution of stress changes in the abutment zones ahead of and adjacent to the cave line (load transfer distance).
f) Determine the entry behavior during mining.

g) Provide thorough descriptions of any ground control problems encountered during mining.

The conditions of stress that have an impact on the longwall face are illustrated by Figure 6.

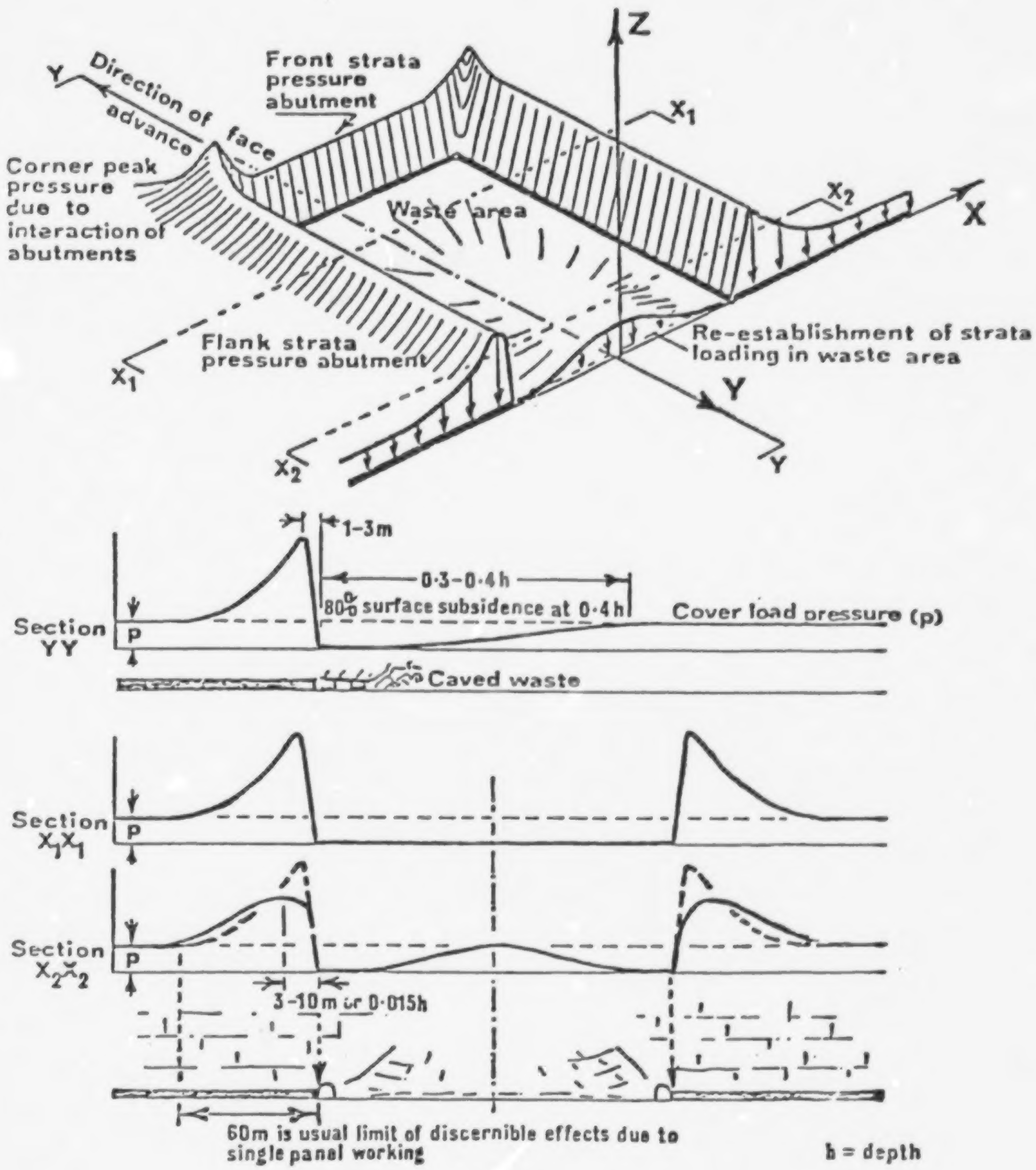
In addition to the above objectives, an instrumentation program should:

a) Provide a capability for monitoring unusual situations that may develop during mining so that remedial measures can be instituted quickly.
b) Provide rock mechanics data for the formulation of design guidelines for future mining operations.
c) Provide rock mechanics data in a format that can be utilized as input into a site-specific rock mechanics model.

Entry stability instrumentation is designed to monitor the performance of the pillars and entry stability; specifically, roof and floor convergence, pillar ribside deformation, and the stability of the rock bolt anchoring horizon are monitored. Instrument layouts are designed to account for pillar geometry, entry geometry and geology in the proposed instrumentation area.

The geology of the station areas should be defined by roof and floor core holes, supplemented by detailed entry mapping of geologic structures. Laboratory testing of physical properties of roof, floor and coal seam material should also be performed. These tests might include:

a) Unconfined compression
b) Brazilian disc tensile
c) Moisture and bulk density determination
d) Triaxial tests on coal
e) Specialty test such as slake durability, Atterberg limits, clay mineralogy, etc., where warranted.


Z
Direction of face advance
Y
Front strata pressure abutment
X_1
Corner peak pressure due to interaction of abutments
Waste area
X_2
X
Flank strata pressure abutment
Re-establishment of strata loading in waste area
Y
X_1
X_2
Y
1-3m
0·3-0·4h
80% surface subsidence at 0·4h
Cover load pressure (p)
Section YY
P
Caved waste
Section X_1X_1
P
Section X_2X_2
P
3-10m or 0·015h
60m is usual limit of discernible effects due to single panel working
h = depth

ABUTMENT STRESSES AROUND A LONGWALL FACE
(AFTER WHITTAKER (1))

FIGURE 6

Pillar instrumentation is designed to provide the following information:

a) Load transfer distance (arch distance)
b) Pillar loading response to stress change

Load transfer distance is an important parameter in the design of barrier pillars because it defines the amount of load a pillar will have to carry. Because barrier pillars are designed to isolate sections of the mine, they should be designed to carry the maximum load which can be imposed on them, assuming complete extraction of the surrounding coal or total failure of any adjacent room pillars.

Pillar loading response instrumentation consists of load cells and extensometers. These instruments are installed to monitor stress changes and deformation within the pillar as the cave line approaches and, finally, as the pillar is mined out.

These instruments provide site-specific data on the geometry of the confined pillar core, the location of the peak abutment stress and the changes in the stress as the pillar is mined out. This information, in conjunction with existing coal strength data and pillar design calculations, allows for fine-tuning of pillar design.

The exact placement of the instrumentation depends on the geomety of the pillar section. However two general rules should apply in locating the instrumentation:

a) The instrumentation area should be located in the central part of the pillar section.
b) The instrumentation area should be located beneath a surface subsidence monitoring line.

Subsidence Studies

Subsidence studies are conducted to evaluate the effect of mining activities on existing surface features such as buildings, pipelines, canals, etc. In many places, legislation requires mine operations to control the extent to which subsidence occurs; this has a direct impact on the specific plans for the underground extraction of coal.

A subsidence monitoring program is designed to determine the commencement, magnitudes and development of the various surface subsidence phenomena as mining progresses. Programs usually provide the following data:

a) Maximum subsidence
b) Subsidence profiles
c) Horizontal movement of the ground surface
d) Strain profiles
e) Determination of the angle of draw
f) The effects of depth and mining geometry on subsidence

The magnitude of surface subsidence and the angles of draw are controlled by the conditions existing at each mine site. The critical parameters are:

a) Overburden depth
b) Surface topography
c) Overburden geology
d) Mine layout
e) Extraction height

The effect of mining on overburden falls into four broad zones that can be categorized as follows:

a) Zone 1: caving and heavy fracturing
b) Zone 2: possible bed separation

c) Zone 3: minimally affected overburden
d) Zone 4: near-surface fissuring

The development of each of these zones depends on:

a) the depth of cover
b) cavability of the near-roof strata
c) the strength of the overburden strata

Figure 7 illustrates the general distribution of these zones.

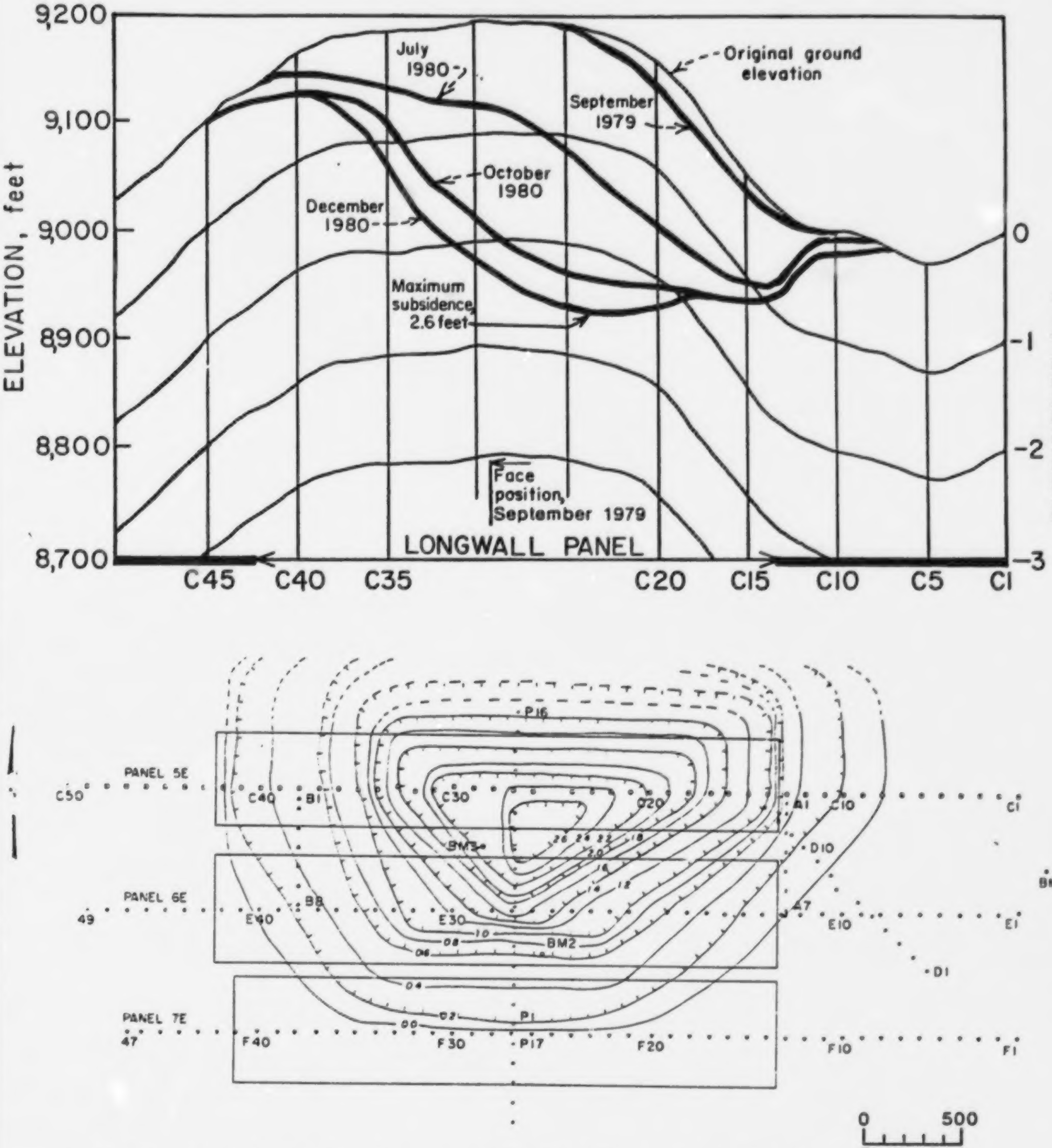
Zone 4 is characterized by fissuring of the near-surface overburden. These fissures normally close with time, and thus have no significant or lasting effect.

Zone 3 forms only where the overburden is thick enough to allow complete development of Zones 2 and 1. Zone 3 is characterized by minimal subsidence effects that do not have any significant or lasting impact on surface features.

Zone 2 is characterized by possible separations along bedding planes. As the face advances, the separations close behind the face at some point in time. The continuity of beds is maintained to a large degree, though cracks develop. These effects also have no significant or lasting impact.

Zone 1 is characterized by disruption and heavy fracturing of the overburden as a result of caving of the roof strata into the mined-out void (the gob). Zone 1 represents the most significant overburden subsidence area; disruption or damage to surface features is usually associated with this zone.

The height of caving in Zone 1 is a function of the decrease in rock density as the roof rock caves (bulking factor). The bulking factor is a function of lithology, structure and strength of the near-seam roof strata in situ. Table No. 3 presents typical bulking factors for rock types common in coal-



SUBSIDENCE PROFILES & SUBSIDENCE CONTOURS

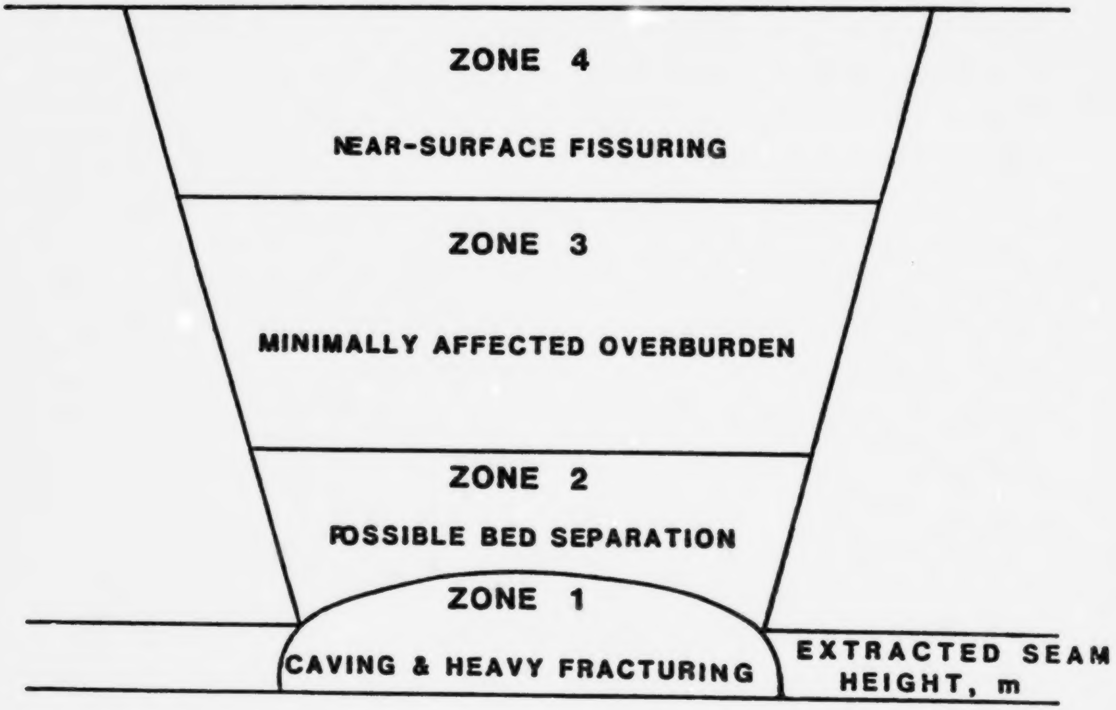
FIGURE 7

bearing sequences. Once the bulking factors for materials in the immediate roof and the extraction height are known, the caving height of Zone 1 can be calculated (Figures 8 and 9).

TABLE 3: BULKING FACTORS FOR DIFFERENT MATERIALS

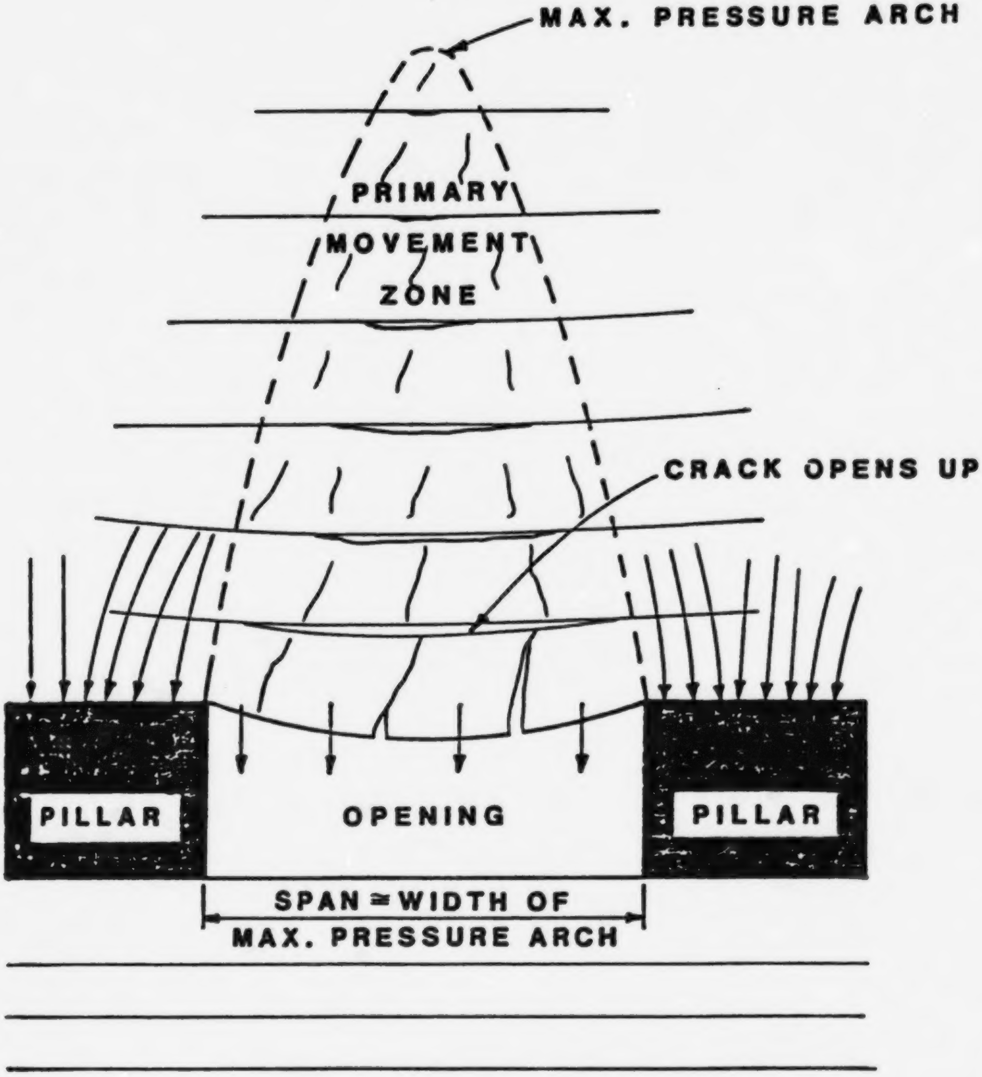
INVESTIGATOR(S)	BULKING FACTOR K	MATERIALS
Kenny	1.53 to 1.64	Coal
	1.7	Shale and Sandstone
	1.45	Marl
Wilson	1.49	Shales ?
Gorrie and Scott	1.33	General rock product
Barry, Nair and Miller	1.12	Sandstones ?
Binns	1.5	Shales ?
Adam, Coeillet and Jacob	1.2	Shales

(Barron & Wright, 1982, CMRC 82-61/C, p. 14)


ZONE 4
NEAR-SURFACE FISSURING
ZONE 3
MINIMALLY AFFECTED OVERBURDEN
ZONE 2
POSSIBLE BED SEPARATION
ZONE 1
CAVING & HEAVY FRACTURING
EXTRACTED SEAM HEIGHT, m

MINING SUBSIDENCE EFFECTS IN OVERBURDEN

FIGURE 8


MAX. PRESSURE ARCH
PRIMARY
MOVEMENT
ZONE
CRACK OPENS UP
PILLAR
OPENING
PILLAR
SPAN ≅ WIDTH OF
MAX. PRESSURE ARCH

CAVING EFFECTS IN ZONE 1

FIGURE 9

Gas Emission Considerations

The amount of gas in coal has particular significance when longwall mining is being contemplated. Longwall mining involves high rates of production, and the amount of methane released from the coal is related to the rate of advance. High rates of methane emission reduce productivity where elaborate and time-consuming methods of ventilation must be instituted.

A small portion of the methane exists in the pore space of the coal, but most exists as gas molecules adsorbed on the coal itself. It is therefore appropriate during exploration to determine the volume of methane and its rate of release from the coal. Standard techniques are available to make these determinations from coal core samples.

It is worth noting that the rate of methane release is related to the porosity of the coal. Coal cleat forms a significant part of that porosity. The development of coal cleat is usually anisotropic, with the most well-developed cleat, the face cleat, having a specific orientation at any one location; the secondary, less well-developed butt cleat is usually at right angles to that orientation. Commonly when a coal face is cut perpendicular to the face cleat, as much as 2½ times the volume of methane is released into the workings as when the coal face is cut perpendicular to the butt cleat.

Hydrogeologic Studies

The objective of mine hydrogeologic studies is to estimate the impact that underground mining has on the hydrogeologic regime. Inflows of water from a mined seam and its surrounding strata can cause difficulties in mine planning and operations. Consequently, the primary objective of a hydrogeologic study is to quantify the mine water inflow. This can be estimated by using field test results in groundwater flow models, computer programs that simulate the hydrogeologic environment of a coal property or mine.

Typical models require the following input:

a) space dimensions of the grid and elements within it
b) hydraulic conductivity
c) boundary conditions
d) initial piezometric elevation at the coal seam level
e) apparent specific yield

Timing factors related to mining events, as well as geologic and hydrogeologic data, are also required by these models.

Calibration of the field data is essential to computer models. Values of the parameters must be selected so that the computer output matches the actual record of aquifer performance.

A field program designed to obtain input data might include some of the following tests:

a) Falling head tests (water is poured into a vertical or near-vertical borehole and the time required for the water level to fall to its original level is recorded).
b) Constant head tests (the quantity of water which has to be poured into the borehole in order to maintain a specific water level is measured).
c) Pumping tests or Lugeon tests (water is pumped into or out of a borehole section between a set of packers and the changes induced by this pumping are measured).

A typical hydrogeologic study of an area planned for longwall mining includes the following data presented in map form:

a) Piezometric surface contour map
b) Model mine area versus time

c) Groundwater model grid system

The following types of data are usually presented in tables:

a) Hydraulic conductivities at specific data points
b) Piezometric profile

LONGWALL MINING IN WESTERN CANADA

MINE DESIGN

Nov/83

John Greenwell

LONGWALL MINING IN WESTERN CANADA

MINE DESIGN

INTRODUCTION

Underground coal mining, to be successful, must achieve an economic balance of development and extraction. Development secures continued productive capacity and extraction represents the return on investment.

Longwall mining involves heavy investment. The return on that investment is high volume single source production. The work of the planner is to design the operation to permit the operator to secure his production at minimum risk.

DESIGN PARAMETERS

1. RESERVES

In-place recoverable reserves must represent at least 8 years of planned productive life before longwall can be considered. To achieve this, the planning function must maintain a 10 year production plan on which the getting, transportation, services and preparation requirements are clearly identified. This,amplified with a detailed 3 year mining plan and operationally implemented with a 1½ year action program, is essential.

1.1 GEOTECHNICAL FACTORS

Recoverable reserves has a precise meaning in longwall terms. While the system can accomodate variations in gradient, changes of seam section, intrusions, faults, water and gas, the basic question is "will it longwall". The geometry for longwall is quite simple (Fig. 1.). The system is dependent upon successful caving of the waste to an extent where the caved material fills the void, consolidates, and affords support to the upper strata. Accordingly, all reserves must be examined to assess their caveability. Caved material bulks and the bulking factor for coal measure strata has been quoted at between 1.20 and 1.50. The importance of this factor can be seen in Figure 1 as it is an important parameter in determining the mechanical roof support required. The lower the bulking factor the bigger (stronger) the support required. When a strong and difficult to break bed is present at an above-seam horizon, the "bulking factor" of the material between the seam and that bed is critical if successful caving is to occur.

The planner must examine the strata column and determine the postion of strong beds, in the roof above the seam. A "strong" bed can be considered for example as a finely grained massive sandstone, exceeding 13,000psi unconfined compressive strength, and more than 5 ft in thickness. Therefore, for the reserves being examined, the following action is required:-

(a) From borehole and any other data examine the near seam strata column and determine the horizon of the first strong bed (H)

(b) Prepare the Iso-ratio Plan from the information derived. (Figure 2) where the iso-ratio lines have the following value:-
$\frac{H}{h}$ (extraction height)

(c) Any area with a ratio value of less than 4 can be considered problematical from the viewpoint of achieving successful caving condition i.e caved material will not fill the void. This assumes a conservative bulking factor of 1.25.

With condition c, further investigation is needed:-

(i) Review available historical data for the seam for roof problems.

(ii) Assess strata caveability by observation of pillaring districts.

(iii) Determine floor strength and its ability to take the higher imposed loads required to induce breaking of the stronger roof beds.

Where very strong beds are positioned beyond Height "H", the possibility of periodic weights and their effect on longwall operations must be examined. These result in loss of roadway stability and severe roof control problems on the face. It is necessary to:-

(a) Determine the thickness and strength of the material.

(b) Compare this data with known and recorded situations.

(c) Perform subsidence surveys to establish strata behavioural patterns.

From this information, the Planner must determine an extraction pattern to minimize periodic weights. This pattern will be based upon:-

(a) Increase face lengths to induce strata fracturing.

(b) Leave coal barriers between pre-determined panels sufficient to support the upper strata without collapse.

(c) Consider total extraction of all pillars to create gob dimensions which will secure settlement of the whole strata column.

Figure 3 provides an example of progressive longwall methodology to meet difficult mining circumstances. It depicts:-

(a) Initial room-and-pillar mining.

(b) Longwall with continued capacity for room-and-pillar.

(c) Development of rationale for panel working with upper strata barrier pillars.

(d) Flexibility in the numbers of entry drivages to achieve environmental control.

1.2 RESERVES GEOMETRY

The geometry of the reserves is a major factor in longwall mining. Faces can be lengthened, shortened and turned but all three factors affect performance. The basic aim is for a uniform, repetative pattern within the mining boundaries. (Fig 4). This establishes stability and balance for the mining program. A further constraint upon geometry is the major fracture patterns associated with previous tectonic activity. The break pattern and density must be determined for any area under consideration. To minimize risk, entry and face alignment must not parallel any line of break.

The third dimension in reserves geometry is gradient. Currently longwall mining can accomodate gradients of up to seventy degrees along the line of face and at least twenty-one degrees along the line of advance. Given this flexibility gradient considerations then evolve on water and gas management. Both water and inflammable gas must be kept from the working area and panel configuration must reflect this requirement.

1.3 EXTERNAL CONSTRAINTS

The end result of out-of-mine constraints is usually a support pillar. Damage to the environment, or existing units within that environment, must be minimal. In planning for longwall, major extraction areas should not inter-face with any sensitive surface feature. Figure 5 shows a longwall retreat area planned to accomodate external constraints.

2. MINING CONFIGURATION

Three longwall alternatives are open to the operator. These are advance; retreat; and advance/retreat (hybrid). A comparison of the three systems is outlined in TABLE 1.

2.1 ADVANCE LONGWALL (Figure 6).

With this system, the face advances from the main access roads into the area to be exploited. Entries are formed with the face and are maintained through the gob for the life of the unit.

Once the first panel has been completed, a second panel will be advanced alongside it with either a protection pillar between the two units, or with the mothergate of the first unit becoming the tailgate of the second face. Re-use of gates has obvious attractions, but can incur heavy roadway maintenance costs.

The principal advantage of the advancing system is that it requires a minimum of development, coal production is quickly realized, and development costs are not deferred. However, overall costs could be increased because of the roadway maintenance factor.

A limiting factor on the system is the roadway formation program coupled with the placing of gateside packs necessary for roadway stability. This program can place a severe restraint on the production potential of the unit.

2.2 RETREAT LONGWALL (Figure 7)

The face is retreated away from boundary and the panel is bounded by unmined chain pillars formed during development. These pillars take the abutment loads developed during mining and correct dimensioning of these pillars is essential to the success of the system.

The system has the advantage that the maximum amount of data is available as the panel is fully prescribed before longwall mining commences. However, development costs require careful control.

2.3 ADVANCE/RETREAT LONGWALL (Figure 8)

The system pre-driven roadways are maintained ahead of the face-line and continue to be driven as the face advances.

An advantage to this method is that coal production can commence relatively quickly and also the road formation activity is remote from coal face operations. However, the operation of the system is complex and requires co-ordination of all activities. It should not be attempted in any initial longwall installation until all personnel are completely familiar with the longwall system elements and its equipment components.

3. LONGWALL GEOMETRY

The ideal is to achieve total coal recovery in the area being mined. This means full seam extraction and no remnant coal pillars. In practice, this is rarely achieved. The objective is to achieve the most effective compromise, which will maximize recovery of the resource.

3.1 EXTRACTION SECTION.

It is desirable to provide the best roof and strongest floor possible for the working of the face. Where weak roof or soft floor are present it may be essential to leave roof or floor coal in place to improve the working environment and minimize out-of-seam dilution. This would be of particular importance with Plains coal where the seam is often the strongest member in near-seam stratigraphical column.

Factors affecting the extraction section are:

(a) Seam Thickness: with thin seams there is little choice but to take full extraction to remain economic. Thicker seams above 16½ft. in section are beyond the reach of existing coal cutting equipment and it is here that horizon selection is possible and often technically essential. One approach to thicker coal extraction is to start conservatively and progressively extend height as experience is gained (Figure 9).

(b) Seam Quality: Mining and transporting non-saleable rock is counter-productive. Where dirt partings exist in the seam section they are best left in-situ if at all possible. Inferior coal partings should be considered in a similar manner. One major constraint is spontaneous combustion and in seams susceptible to this the minimum amount of carbonaceous material should be left in waste zones.

(c) Intrusions: Rock intrusions, whether continuous or dispersed, are heavy on equipment and can present a frictional ignition hazard. They are often near the roof or floor and should be left in-place.

The basics of planning the extraction section are to balance the above factors to achieve the best possible horizon control and the maximum clean coal yield, with the roof supports based upon the most competent floor and operating to a clean roof parting.

3.2 FACE AND PANEL LENGTH

There is a general longwall maxim that:

> "The longest possible face coupled
> with the longest possible panel
> give the best results."

Where all the mining factors involved can be given an equal weighting this statement is probably true as it maximizes the ratio of face extraction volume to support pillar volume. It also enhances the ratio of face cutting time to operational delay time. In practice, face and panel lengths are developed to:-

(a) Maximize reserve recovery within the given geometry of those reserves.

(b) Ensure that all equipment operates within design parameters.

(c) Secure the potential for the extraction of adjacent seams of coal.

Within the geotechnical and other constraints affecting design, North American practice is now tending towards increasing face length and extending panel life. This reduces the residual pillar factor so enhancing the operation. However, the major factor governing current trends is Development Geometry and its ability to constantly provide replacement capacity.

4. DEVELOPMENT GEOMETRY

In general, face and panel alignment pre-determine the development direction. Difficulties in development are more than offset by good results from the longwall face. Good face conditions are essential, good development conditions are desireable.

Mining layouts for longwall can be developed using single or multiple entry systems. The number of entries is a factor which can be controlled to minimize the development problem.

For the highest rate of longwall tonnage to development tonnage, the ideal number of entries is one (1) and this entry should be re-used on the succeeding longwall panel. However, operational logistics make it impossible, in practice, to use single entry development. The choice then hinges about the room-and-pillar unit selected for development.

Factors influencing the choice of number of entries are:-

(a) Roof Conditions: if roof support is not an impediment and percentage recovery not a restraint, four or five entry systems may be used to minimize operational problems and achieve optimum development rates. There is ample evidence to support the five-entry system as the most cohesive room-and-pillar unit. However, if support conditions are the determining factor, three or two entry systems could improve development rates despite the limitations they impose on machine availability, face haulage and ventilation.

(b) Ventilation: development drivages, upon completion, must carry the air quantities required by the longwall face with acceptable air velocities. Face quantity is determined by environmental factors such as methane liberation, temperature gradient through the panel and dust production. To carry air quantities as high as 80,000cfm in low or restricted roadways can require four or five entry development.

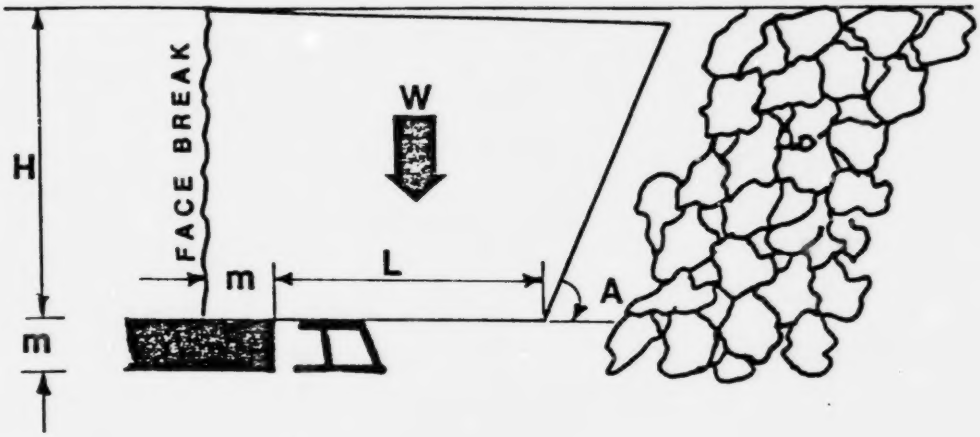
(c) Logistics: the movement of men and equipment, the transportation of mineral, the removal of mine water and placing of mine services should interface as little as possible. Multi-purpose roadways require careful consideration e.g. free-steered vehicles alongside belt conveyors or diesel vehicles in return airways can be counter-productive. On balance, a minimum of 3 entries is indicated.

(d) Percentage Extraction: given the impracticality of the single entry access, a two entry system, leaving a single pillar between adjacent longwall faces, provides the best percentage extraction pattern. However, the pillar is subjected to multiple abutments and must not yield before the second face has worked past it. This requires larger pillars of specific design. To achieve entry integrity and minimize abutment effects the three or five entry system offers advantages. These however, reduce reserve recovery but do allow consideration for pressure-relief entries, which may so enhance roadway conditions that this off-sets any coal loss in pillars.

CONCLUSION

Considerations outlined above have been to achieve a controlled recovery of coal by longwall mining within the constraints imposed by the nature of the reserves to be exploited. Those same considerations must apply to the method of accessing those reserves. A cardinal rule in underground coal mining is "First in - Last out". Roadways formed in the initial development of a mine usually last the life of that mine. They sustain the total mineral flow, carry full mine services and determine the face-working environment. The formation of high-integrity, long-life arteries is not specific to longwall mining and therefore has not been specifically addressed in this seminar paper.

Planning is a kinetic exercise,and is subject to constant change and up-date. For any system certain basic parameters must be in place. The purpose of this paper has been to outline those parameters. The kinetics of developing in-mine knowledge and accomodating equipment improvements will continue to be the site specific elements of planning.



$$g \times S \times H \times \left[(M+L) + \frac{H}{2\tan A} \right]$$

where:

W = Weight on support (lbs)

g - In situ density of material (lb/ft^3)

H - Height of cave (ft)

$$H = \frac{m}{k-1}$$

k = swell factor

A = Cave Angle

m = Extraction height (ft)

L = Breaking length of roof (ft)

S = Center-to-center support spacing

Figure 1 CALCULATION GEOMETRY FOR SUPPORT LOADS

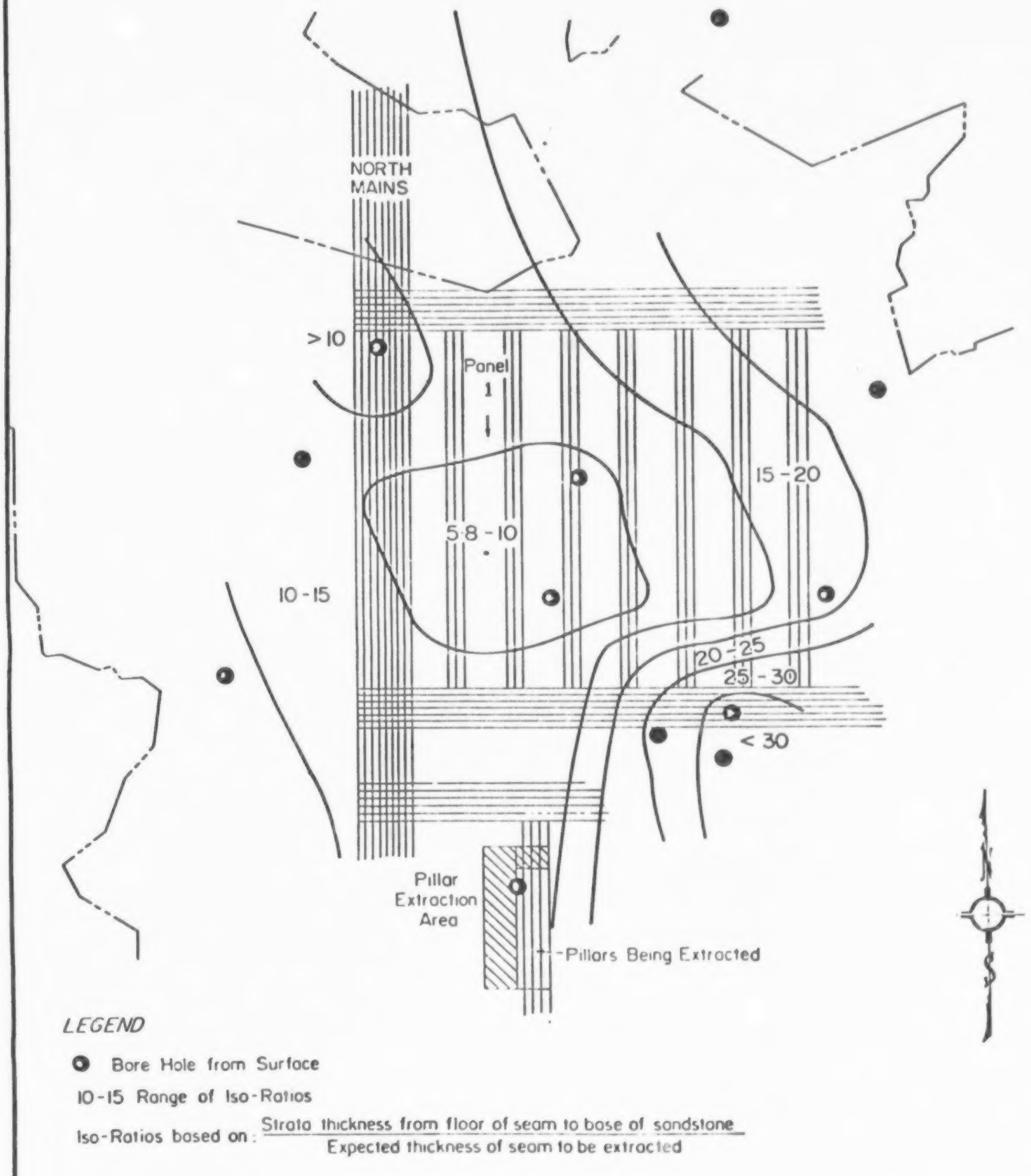

NORTH MAINS
>10
Panel 1
5·8 - 10
10 - 15
15 - 20
20 - 25
25 - 30
< 30
Pillar Extraction Area
Pillars Being Extracted
N
S
LEGEND
Bore Hole from Surface
10-15 Range of Iso-Ratios
Iso-Ratios based on : Strata thickness from floor of seam to base of sandstone / Expected thickness of seam to be extracted
1000 500 0 1000 2000

Figure 2

PROPOSED LONGWALL LAYOUT

DISTRIBUTION OF ISO-RATIOS

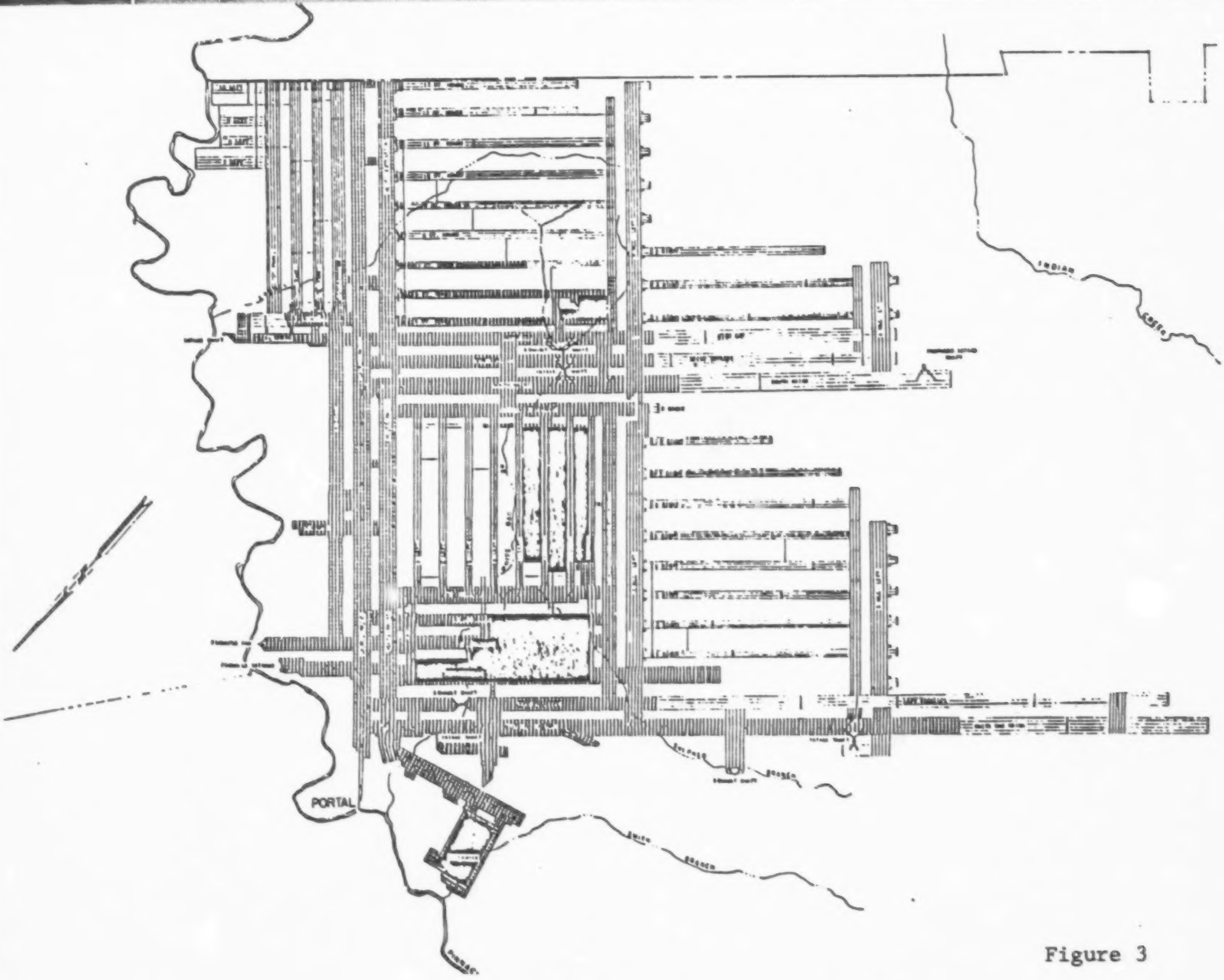

INDIAN CREEK
PORTAL

Figure 3

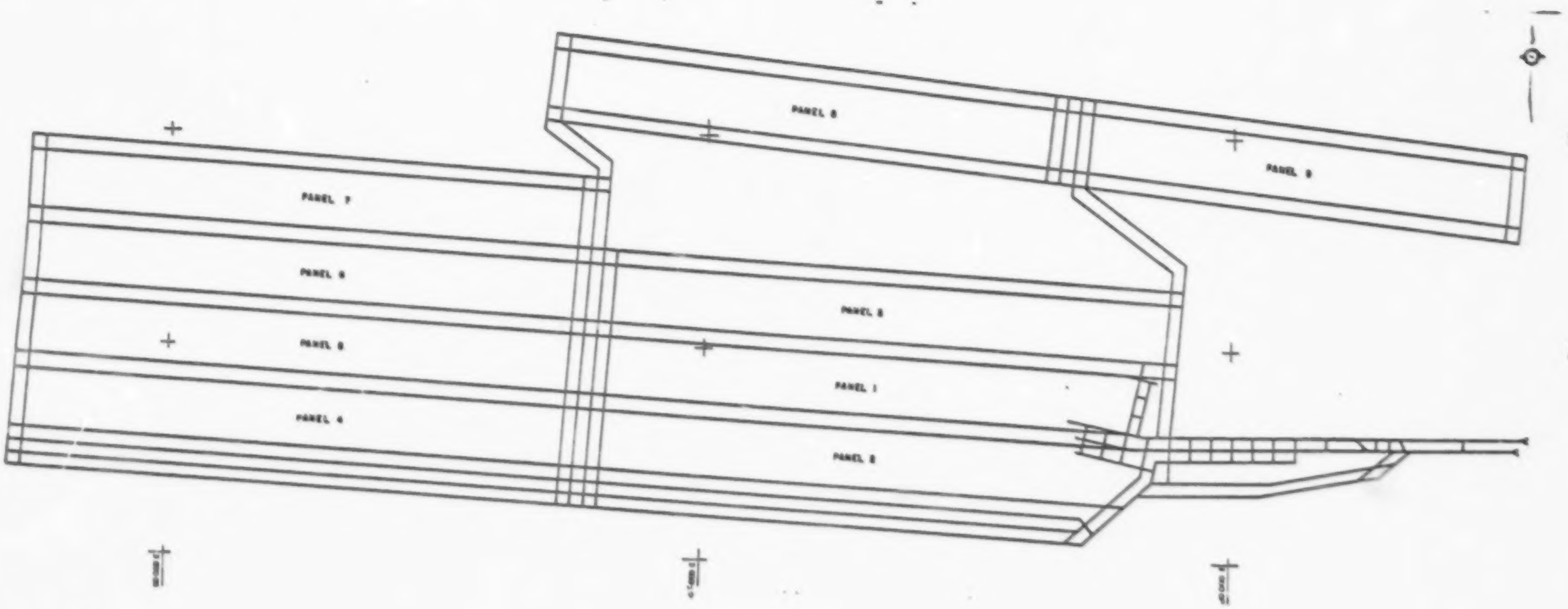

PANEL 8
PANEL 9
PANEL 7
PANEL 6
PANEL 5
PANEL 4
PANEL 3
PANEL 1
PANEL 2

Figure 4

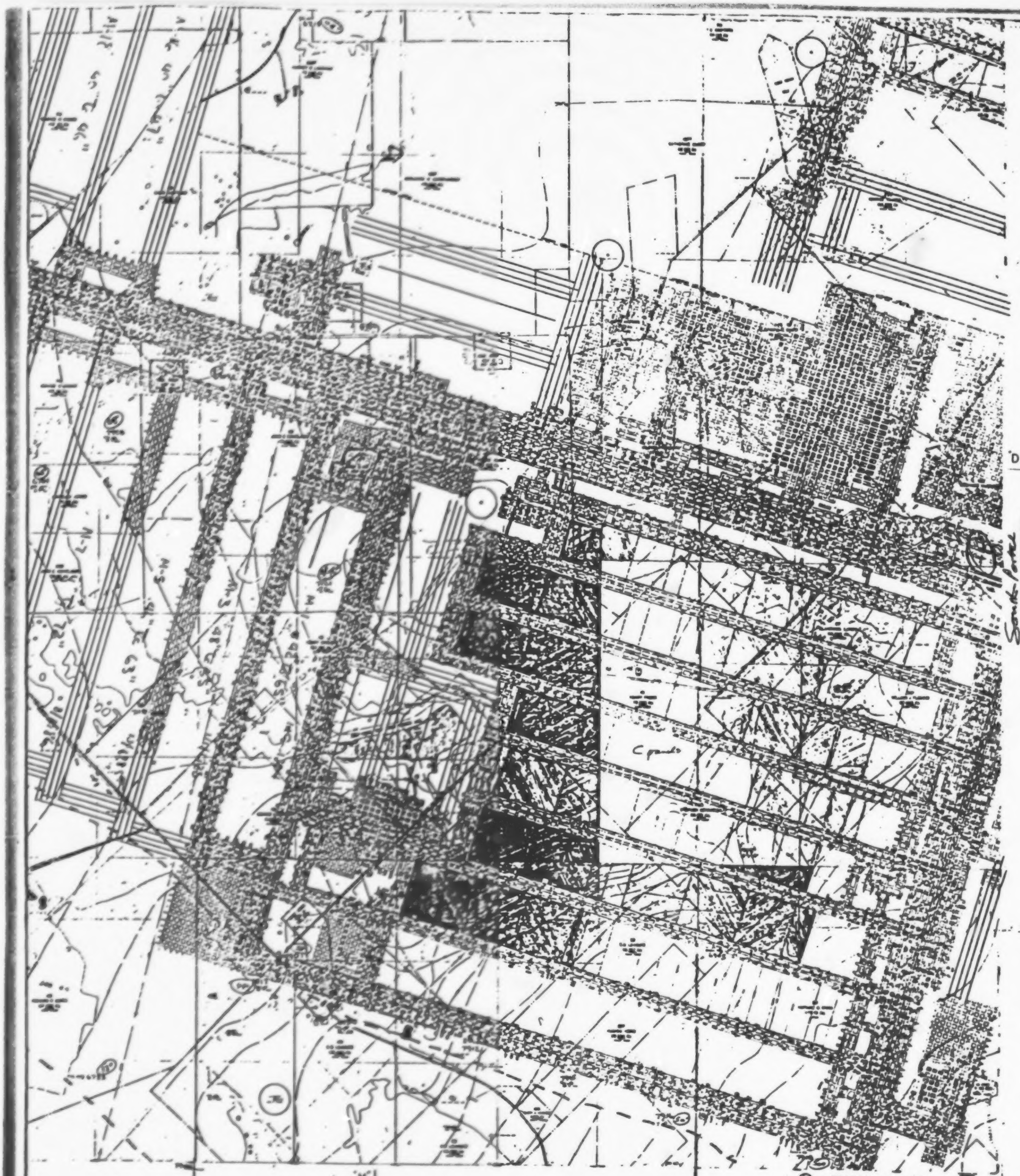
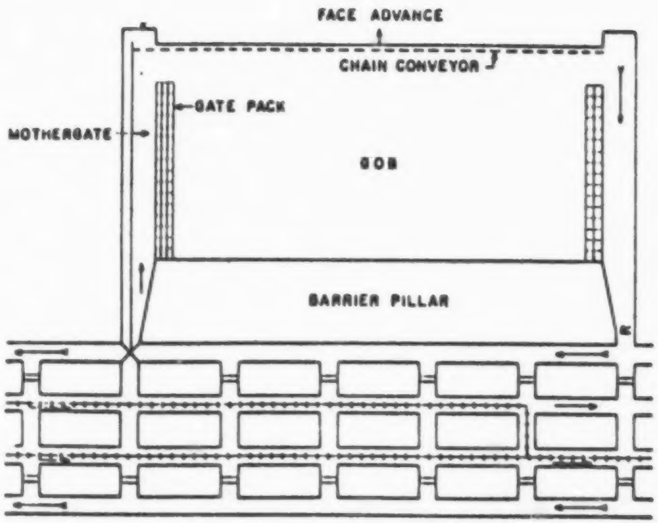
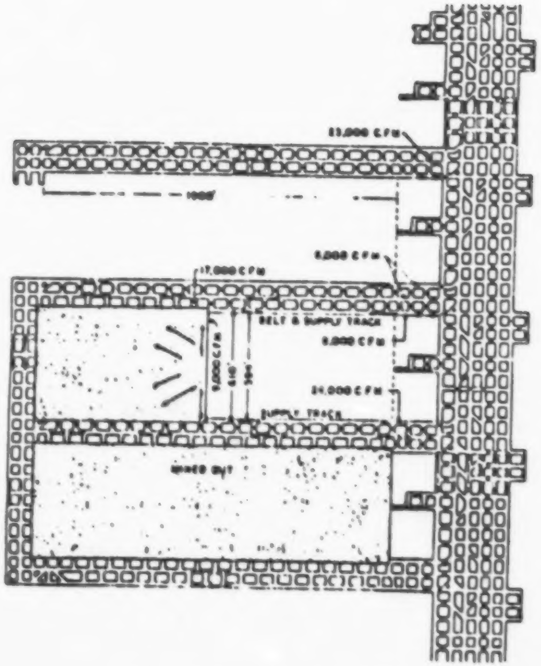

"D"
South Pond
C pond
"M"
POSTED TO 7-1-82
1" = 400'
1" = 400'

Figure 5


FACE ADVANCE
CHAIN CONVEYOR
GATE PACK
MOTHERGATE
GOB
BARRIER PILLAR

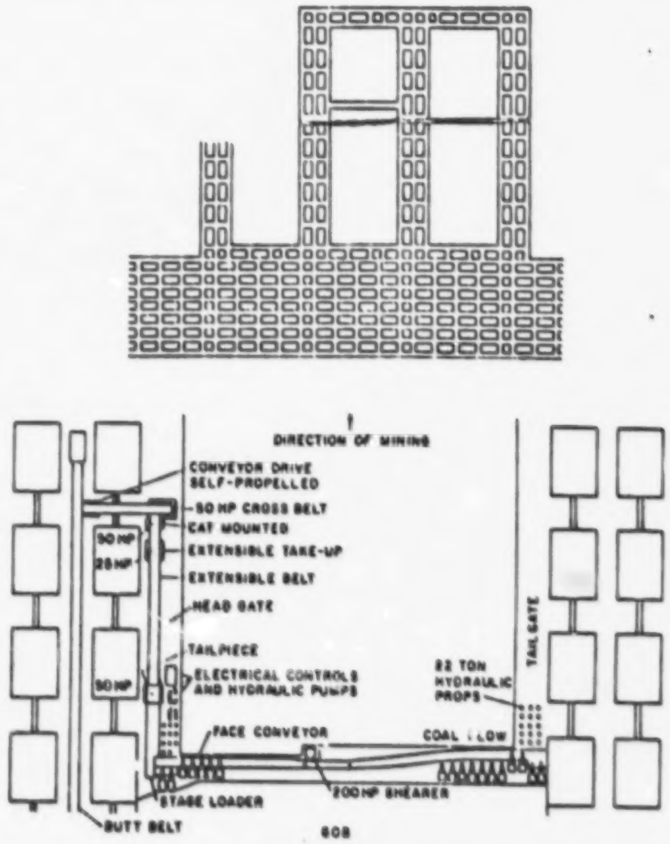
Example of a Typical Longwall Advance System.

Figure 6


33,000 CFM
1000'
8,000 CFM
17,000 CFM
BELT & SUPPLY TRACK
9,000 CFM
610'
584'
8,000 CFM
24,000 CFM
SUPPLY TRACK
MINED OUT

. Typical Longwall Retreat System.

Figure 7


DIRECTION OF MINING
CONVEYOR DRIVE SELF-PROPELLED
50 HP CROSS BELT
CAT MOUNTED
EXTENSIBLE TAKE-UP
EXTENSIBLE BELT
HEAD GATE
TAILPIECE
ELECTRICAL CONTROLS AND HYDRAULIC PUMPS
FACE CONVEYOR
STAGE LOADER
BUTT BELT
50 HP
25 HP
50 HP
COAL FLOW
200HP SHEARER
22 TON HYDRAULIC PROPS
TAILGATE
608

An Alternate Advance and Retreat System.

Figure 8

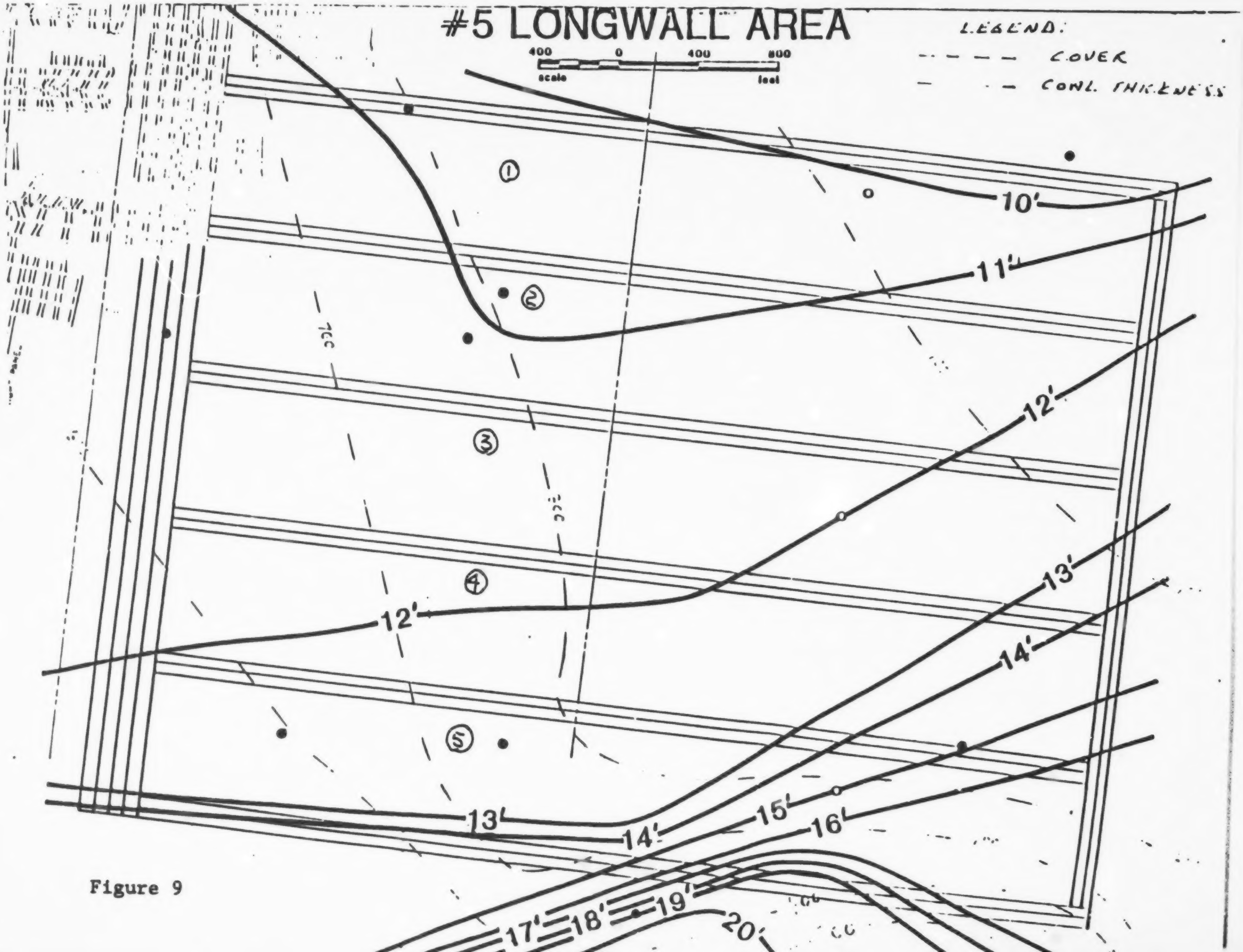

#5 LONGWALL AREA
400 0 400 800
scale feet
LEGEND:
COVER
COAL THICKNESS
①
②
③
④
⑤
10'
11'
12'
12'
13'
14'
13'
14'
15'
16'
17'
18'
19'
20'
700
700

Figure 9

COMPARISON OF LONGWALL MINING CONFIGURATIONS

ITEM	ADVANCE LONGWALL	RETREAT LONGWALL	HYBRID LONGWALL RETREAT
1. Mining Related Data	Restricted to borehole data and data obtained from adjacent mining activities.	Maximum amount of data available.	As for advance system, supplemented by limited additional data from advanced roadway development.
2. Roadway Development	Roadways are developed with the face advance. Single steel supported entries are normal.	Roadways are fully developed before face installation. Single or multi entry systems may be used.	Roadways are developed ahead of the face. Single or multi entry systems may be used.
3. Roadway Maintenance	Heavy roadway maintenance requirement usual where thick seams are extracted.	Limited roadway maintenance required. Attention to front abutment zone may be required.	Heavy maintenance requirement for single entry system. Attention to abutment zone may be required for multi entry system.
4. Roadside Packs	Required to provide roadway stability.	Not normally required.	Required if single entry system adopted.
5. Reserve Recovery	Maximized with this system, particularly if roadways can be reused.	Development configuration affects recovery.	Development configuration affects recovery.
6. Face Extraction - Panel Length	Can exceed prescribed length if mining conditions are favourable.	Prescribed.	Can exceed prescribed length if mining conditions are favourable.
7. Mining Support Equipment Conveyors, Pipelines, etc.	Installed as face advances.	Fully installed at commencement of face operations. Withdrawn as face retreats.	Installed as face advances.

Table 1

COMPARISON OF LONGWALL MINING CONFIGURATIONS

ITEM	ADVANCE LONGWALL	RETREAT LONGWALL	HYBRID LONGWALL RETREAT
8. Development Equipment	Usually specialized or heavily manpower intensive.	No special requirements unless single entry systems envisaged.	No special requirements unless single entry systems are envisaged.
9. Ventilation System	Relatively simple, must accommodate ventilation for headings.	Simple and uncomplicated.	Complex arrangements necessary to ensure proper ventilation of advance headings.
10. Spontaneous Combustion	Can be the source of continuing problems.	Can be more readily controlled - problems left behind as face retreats.	This system is not suitable if spontaneous combustion problems are to be anticipated.
11. Mining System	Special roadhead arrangement necessary to accommodate roadway drivage. Packs required along roadside.	Simple.	Complex activity on both development and longwall must be coordinated. Single entry systems require roadway packs following face extraction.
12. Environmental Control	Difficult at face ends.	Relatively simple.	Difficult at face ends due to advance drivage activity.
13. Equipment Recovery	May be difficult, all face and other equipment must be transported out along roadways which may have converged.	Equipment is recovered as face retreats.	As for advance - additional large items of equipment require transportation.

Table 1 (Cont'd)

COMPARISON OF LONGWALL MINING CONFIGURATIONS

ITEM	ADVANCE LONGWALL	RETREAT LONGWALL	HYBRID LONGWALL RETREAT
14. Face and Development Supplies	Must be transported and stored until used in single roadway subject to convergence. Distance increases as face advances.	Relatively simple since transport will be through unstressed roadways and distance decreases as face retreats.	Similar to advance but additional difficulties may arise in transporting materials across the face line.
15. Initial Face Installation	Presents a short route for transport and installation.	May require lengthy transportation and require longer installation time.	Same as for advance.
16. Expenditure Required Before Face Installation	Reduces initial development expenditure to a minimum.	Requires maximum expenditure on development.	Require more than minimum expenditure as initial development expenditure determined by amount of roadway maintained ahead of face advance.
17. Manpower at Face	Development work crew must be included. Construction of roadway packs requires additional manpower and equipment.	Face operations crew only.	Significant number of additional persons employed on development work. Single entry system will require roadway pack erection crew.
18. Mining Risk	Highest, since only minimum of information on expected mining conditions available.	Lowest since maximum amount of mining data available.	High since only limited data data available at outset of mining.

Table 1 (Cont'd)

LONGWALL MINING IN WESTERN CANADA

EQUIPMENT

H.D. Owen
Manager of Engineering
Norwest Resource Consultants
November, 1983

SLIDE 1

INTRODUCTION

WITH THE AID OF SLIDES

- DESCRIBE LONGWALL METHODS
- STRESS SYSTEMS APPROACH
- DESCRIBE EQUIPMENT AND OPERATING PARAMETERS FOR:

DEVELOPMENT
TRANSPORTATION
LONGWALL OPERATION
POWER SUPPLY
SIGNALLING-COMMUNICATION,
MONITORING SYSTEMS

SLIDE 2

LONGWALL METHODS

EQUIPMENT
ALTERNATIVE LAYOUTS
PREFERRED LAYOUT
MINE LAYOUT
SYSTEMS INTEGRATION

SLIDE 3

OPERATIONS SUPPORT

DEVELOPMENT
TRANSPORTATION - MEN
- MATERIALS
- MINERAL
POWER SUPPLIES
SIGNALS COMMUNICATIONS/MONITORING
OTHERS - VENTILATION
- WATER
- DUST
- EMERGENCY SERVICES
- ETC.

SLIDE 4

SELECTION OF DEVELOPMENT METHOD

GEOLOGICAL/GEOTECHNICAL
ROADWAY CONFIGURATION
. X-SECTION
. NO. OF ENTRIES
SUPPORT OF ROOF AND SIDES
MATERIAL HANDLING
REQUIRED PRODUCTIVITY
COSTS

SLIDE 5

DEVELOPMENT SYSTEMS

CONTINUOUS MINER
BOOM MINER
EIKHOFF MINER
IN SEAM MINER

SLIDE 6

DEVELOPMENT SYSTEMS - DISADVANTAGES

CONTINUOUS MINER - CYCLIC OPERATION
- RECTANGULAR EXCAVATION
- REQUIRES GOOD FLOOR

IN SEAM MINER - SINGLE ENTRY
- LIMITED HEIGHT
- RECTANGULAR EXCAVATION

BOOM MINER - SUSPECT MOBILITY
- CYCLIC OPERATION
- REQUIRES GOOD FLOOR

EIKHOFF MINER - NOT YET PROVEN-AMERICA
- MULTI ENTRY-COMPLEX

SLIDE 7 **TRANSPORTATION SYSTEMS - SELECTION**

- MINE LAYOUT
- DUTY
- REGULATIONS
- REQUIRED LABOUR SKILLS
- COSTS

SLIDE 8 **TRANSPORTATION SYSTEMS AVAILABLE**

DIESEL - FREE STEERED
- RAIL

BATTERY - FREE STEERED
- RAIL

ROPE/RAIL - ENDLESS
- GRAVITY
- MAIN AND TAIL

CONVEYOR

SLIDE 9 TRANSPORTATION RAIL MOUNTED SYSTEMS

MONO RAIL - FLOOR
- SUSPENDED

TRAPPED RAIL - FLOOR
- SUSPENDED

CONVENTIONAL

SLIDE 10 TRANSPORTATION SYSTEMS - DISADVANTAGES

DIESEL-FREE STEERED/
CONVENTIONAL RAIL - LIMITED GRADE
- VENTILATION
- MAINTENANCE/ROADS/ EQUIPMENT

BATTERY FREE STEERED/ - LIMITED GRADE
CONVENTIONAL RAIL - LIMITED ENDURANCE
- MAINTENANCE/ROADS

ROPE/RAIL - MAINTENANCE/SKILLS
- COSTS
- FLEXIBILITY

SLIDE 11

THE LONGWALL

FACE SUPPORTS
FACE CONVEYOR
COAL SHEARER
STAGE LOADER
EQUIPMENT CARRIER
BELT CONVEYOR

SLIDE 12

SYSTEM SELECTION - SUPPORTS

GEOLOGICAL/GEOTECHNICAL

- SUPPORT RESISTANCE
- SUPPORT RANGE/COLLAPSED HEIGHT
- BEARING PRESSURES
- CONFIGURATION

EXTRACTION DEPTH/METHOD
MINE LAYOUT
OTHER OPERATIONS IN SIMILAR CONDITIONS
OTHERS

- REGULATIONS
- COSTS, ETC.

SLIDE 13

OTHER EQUIPMENT SELECTION

- COMPATIBILITY
- CAPACITY
- REQUIRED LIFE
- FACE CONDITIONS
    - COAL STRENGTH
    - DUST
    - METHANE
    - WATER
    - LENGTH/INCLINATION
- COST

SLIDE 14

POWER SUPPLY REQUIREMENT

- FLAMEPROOF EQUIPMENT
- INTRINSICALLY SAFE CONTROL SYSTEMS
- ADEQUATE CAPACITY
- GOOD VOLTAGE REGULATION
- RELIABLE OPERATION
- HIGH STANDARD OF PROTECTION
- RESTRICTED GROUND FAULT
- EASY FAULT LOCATION/MAINTENANCE
- REASONABLE COSTS

SLIDE 15 POWER SYSTEM COMPONENTS 550/1100 V

FLAMEPROOF MOTORS

- T.E.F.C.
- WATER COOLED

CABLES

- SCREENED POWER CONDUCTORS
- UNINSULATED GROUND CONDUCTOR
- INSULATED CONTROL CONDUCTORS

SLIDE 16 POWER SYSTEM COMPONENTS 550/1100 V

FLAMEPROOF CONTACTORS

- INDIVIDUAL ISOLATION
- VACUUM CONTACTOR
- 7½ VOLT PROTECTED CONTROL CIRCUIT
- CIRCUIT TEST FACILITY
- REMOTE OPERATION
- OVERLOAD/GROUND FAULT
- GROUND FAULT LOCKOUT

FLAMEPROOF TRANSFORMER

- H.T. ISOLATOR
- RESTRICTED NEUTRAL

SLIDE 17 **POWER SYSTEM COMPONENTS 4160/6600 V**

DISTRIBUTION CABLE

- SCREENED POWER CONDUCTOR
- UNINSULATED GROUND CONDUCTOR

FLAMEPROOF CONTACTOR

- AS FOR L.T.

CIRCUIT BREAKER

- MANUALLY OPERATED
- REMOTE TRIPPING
- AS FOR CONTACTOR

SURFACE TRANSFORMER

- RESTRICTED NEUTRAL
- LIMITED FAULT CAPACITY

SLIDE 18 **SIGNALS/COMMUNICATIONS/MONITORING**

SIGNAL SYSTEMS

- INTRINSICALLY SAFE
- FAIL SAFE
- EMERGENCY STOP/INDICATION
- LOCKOUT/INDICATION
- PRE-START WARNING
- AUDIBLE SIGNALS

COMMUNICATIONS

- INTRINSICALLY SAFE
- BROADCAST SPEECH
- COMPATIBLE WITH TELEPHONE

SLIDE 19

SIGNALS/COMMUNICATIONS/MONITORING

MONITORING SYSTEMS/ENVIRONMENT/EQUIPMENT

- **INTRINSICALLY SAFE**
- **AVAILABLE SYSTEMS**
- **TRANSDUCERS**
- **DATA PRESENTATION**

SEMINAR - LONGWALL MINING IN WESTERN CANADA

CASE STUDY

PLANNING AND ENGINEERING A LONGWALL DEMONSTRATION FOR SMOKY RIVER COAL LIMITED

BY: T. ROBSON
MANAGER, UNDERGROUND MINES
SRCL
P.O. BOX 2000
GRANDE CACHE, ALBERTA
CANADA

NOVEMBER 1983

INTRODUCTION

- McIntyre/Smoky River Coal are continually seeking means to improve competitiveness
- Longwall mining in SRCL's mountain coal environment has been evaluated and, if successful, would be cost effective, particularly in steeper areas
- Implementation is a high risk venture
- Joint Industry/Government risk sharing concept proposed
- Case study describes planning and engineering carried out by McIntyre for CANMET
- Site specific to SRCL, but much of work is of value to others

FORMAT

PART 1	PREVIOUS EXPERIENCE
	SYSTEM CHARACTERISTICS
	CURRENT STATUS SRCL
	DESIGN CONSIDERATIONS
	9G-4 MINE DESIGN
PART 2	OPERATIONS
	PERFORMANCE PROJECTIONS
	TENDERS
	DEMONSTRATION MANAGEMENT
	ECONOMICS
	FINDINGS AND CONCLUSIONS

PART 1

PROBLEMS WITH PREVIOUS LONGWALLS AT MINES NO. 2 AND 5

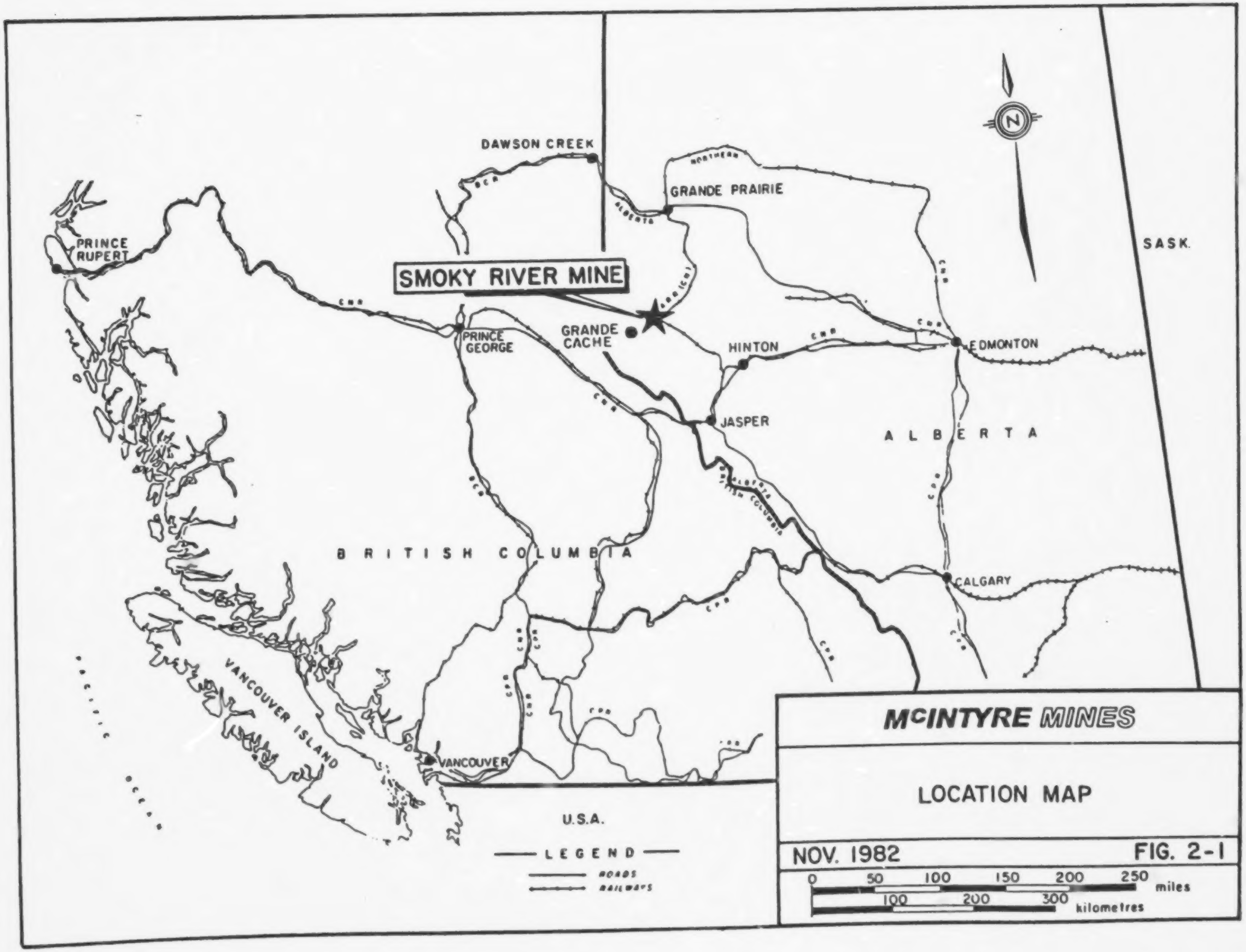
- INHERENT DEFICIENCIES IN SUPPORTS
- ROOF CONTROL POOR
- FLOOR PENETRATION
- DELAYS IN EQUIPPING
- ADJACENT MINING OPERATIONS
- DIVERSION OF MANPOWER
- VENTILATION

LONGWALL SYSTEM

- CHARACTERISTICS

	ROOM AND PILLAR	LONGWALL
MIN. HEIGHT	3 FT.	3 FT.
MAX. HEIGHT	10 - 13 FT.	20 FT.
LIMITING GRADE	±15° - 18°	+45°
MINING SEQUENCE	COMPLEX	SIMPLE
EQUIPMENT MOVEMENT	FREQUENT	INFREQUENT
ROOF CONTROL	UNPREDICTABLE	SYSTEMATIC
EFFECT OF WATER	SIGNIFICANT	MODERATE
VENTILATION/METHANE/DUST CONTROL	COMPLEX	SIMPLE
EFFECT OF GRADIENT ON OMS	SEVERE	MODERATE
SAFETY	ADEQUATE	GOOD
CAPITAL COST	MEDIUM	HIGH
PRODUCTIVITY	MEDIUM	HIGH
OPERATING COST	MEDIUM	LOW

- IMPROVES - RESERVE RECOVERY
  - SAFETY
  - COMPETITIVENESS

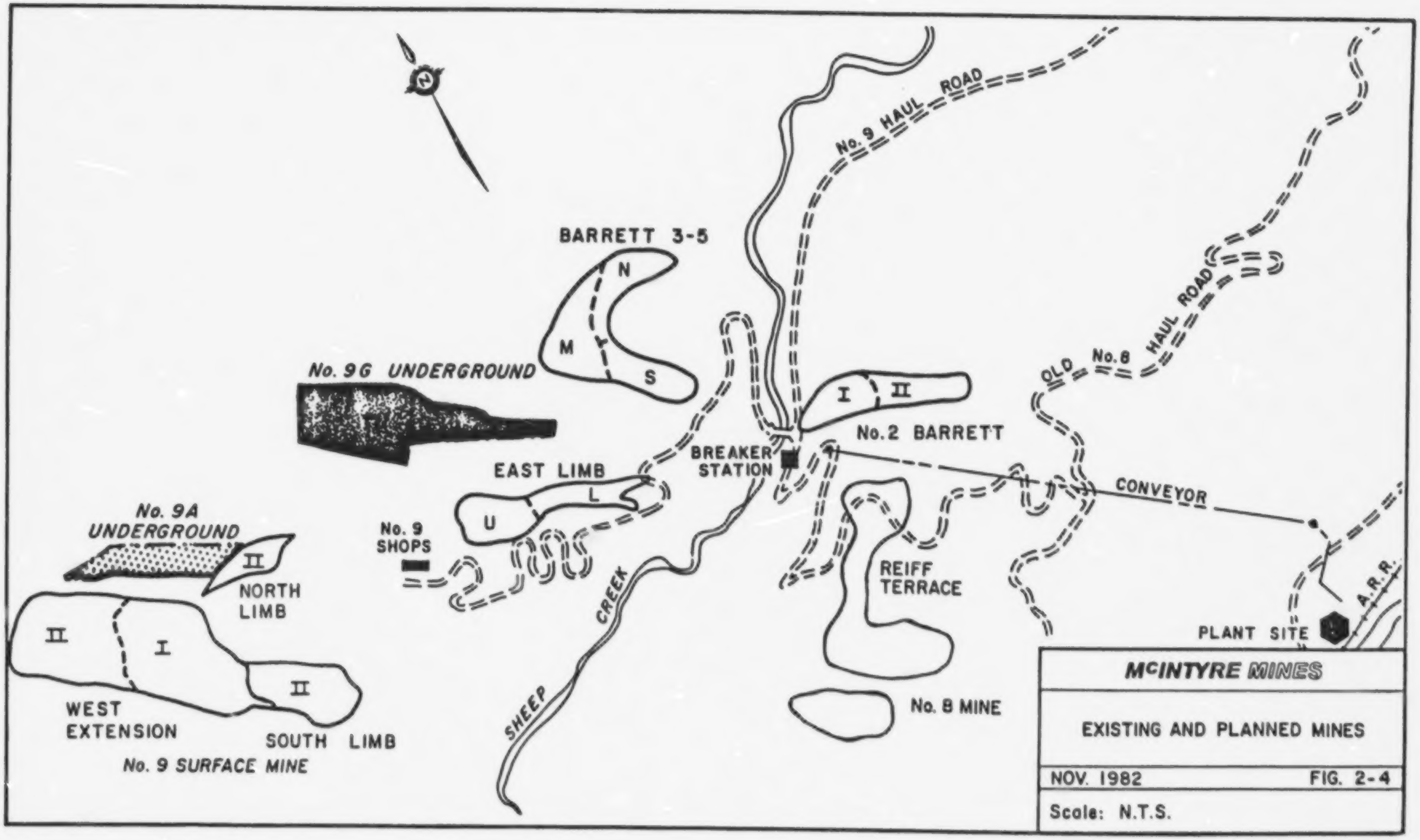

SMOKY RIVER MINE
DAWSON CREEK
GRANDE PRAIRIE
PRINCE RUPERT
PRINCE GEORGE
GRANDE CACHE
HINTON
EDMONTON
JASPER
CALGARY
VANCOUVER
BRITISH COLUMBIA
ALBERTA
SASK.
U.S.A.
VANCOUVER ISLAND
PACIFIC OCEAN
NORTHERN
ALBERTA
CNR
BCR
CPR
N
LEGEND
ROADS
RAILWAYS
0 50 100 150 200 250 miles
100 200 300 kilometres

McINTYRE MINES

LOCATION MAP

NOV. 1982

FIG. 2-1

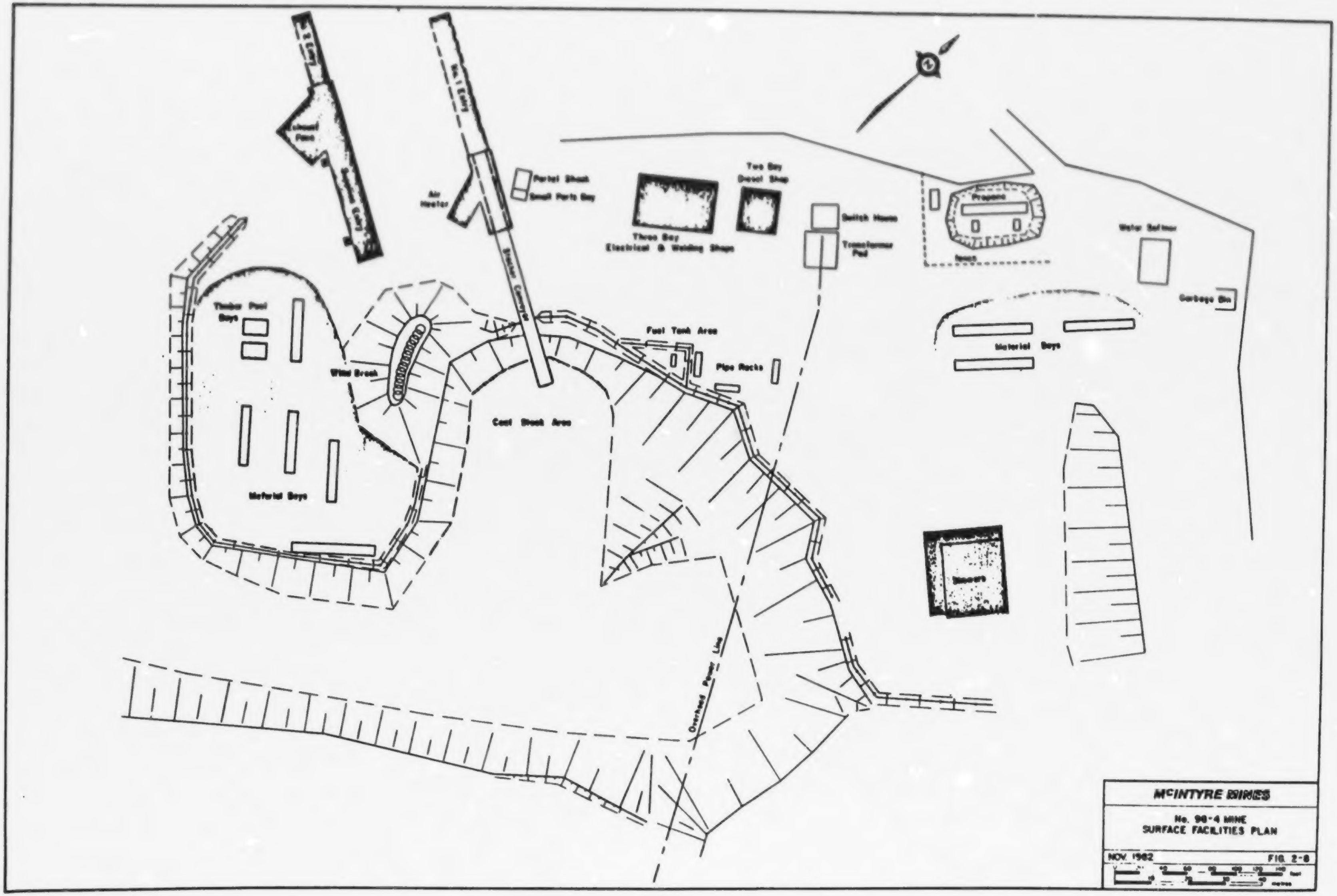

No. 9 HAUL ROAD
OLD No. 8 HAUL ROAD
BARRETT 3-5
N
M
S
No. 9G UNDERGROUND
No. 2 BARRETT
I
II
BREAKER STATION
CONVEYOR
EAST LIMB
L
U
No. 9 SHOPS
No. 9A UNDERGROUND
II
NORTH LIMB
II
I
II
WEST EXTENSION
SOUTH LIMB
No. 9 SURFACE MINE
SHEEP CREEK
REIFF TERRACE
No. 8 MINE
PLANT SITE
A.R.R.

McINTYRE MINES

EXISTING AND PLANNED MINES

NOV. 1982 FIG. 2-4

Scale: N.T.S.

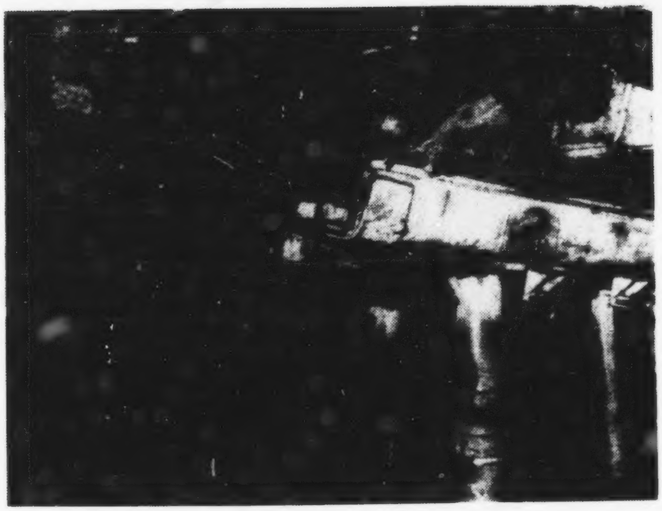

No. 2 Entry
Supplies Entry
No. 1 Entry
Air Heater
Portal Shack
Small Parts Bay
Stacker Conveyor
Three Bay
Electrical & Welding Shops
Two Bay
Diesel Shop
Switch House
Transformer Pad
Propane
Water Softner
Garbage Bin
Material Bays
Timber Pool Bays
Wind Break
Material Bays
Coal Stock Area
Fuel Tank Area
Pipe Racks
Overhead Power Line
feet
metres

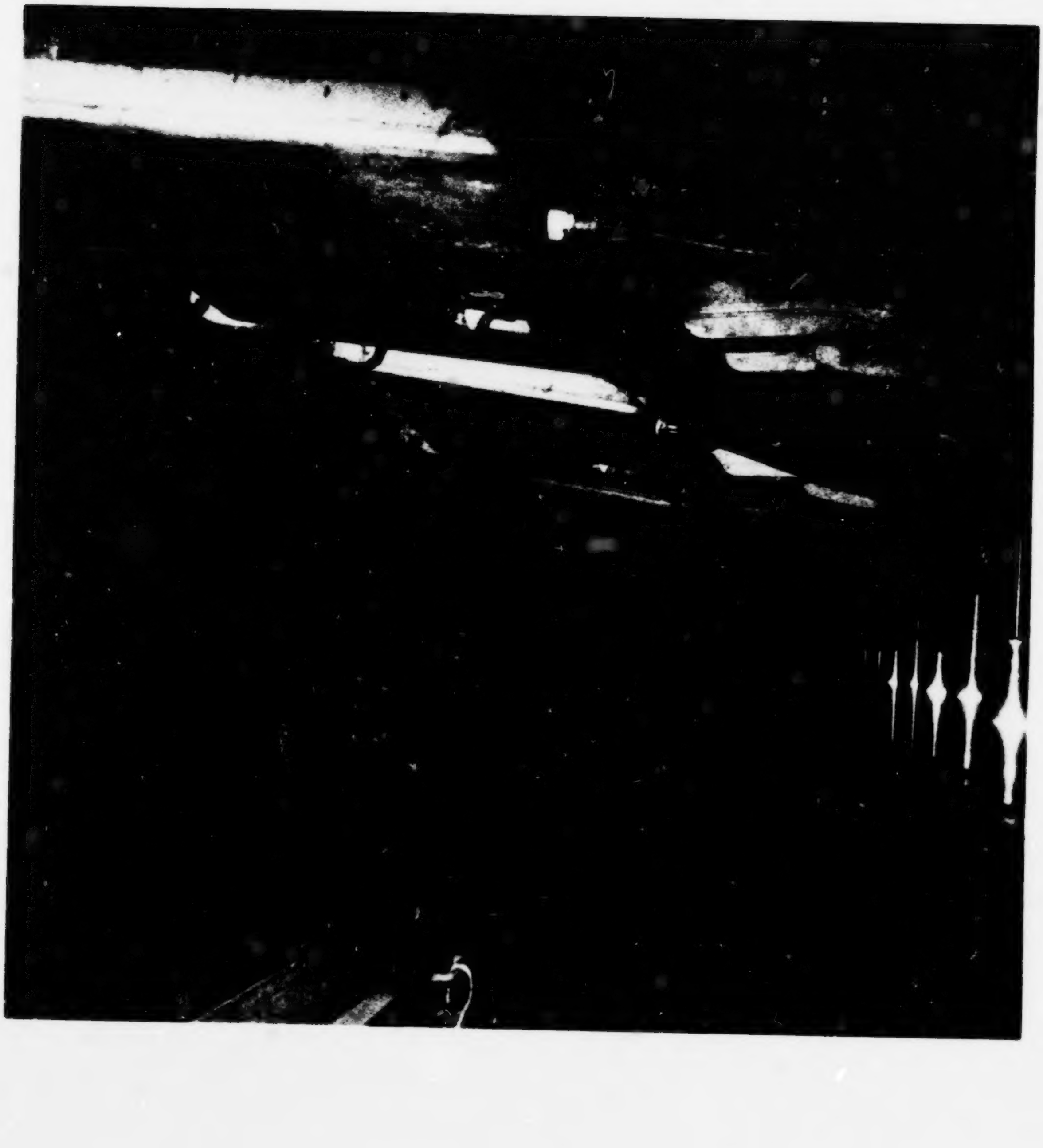
McINTYRE MINES

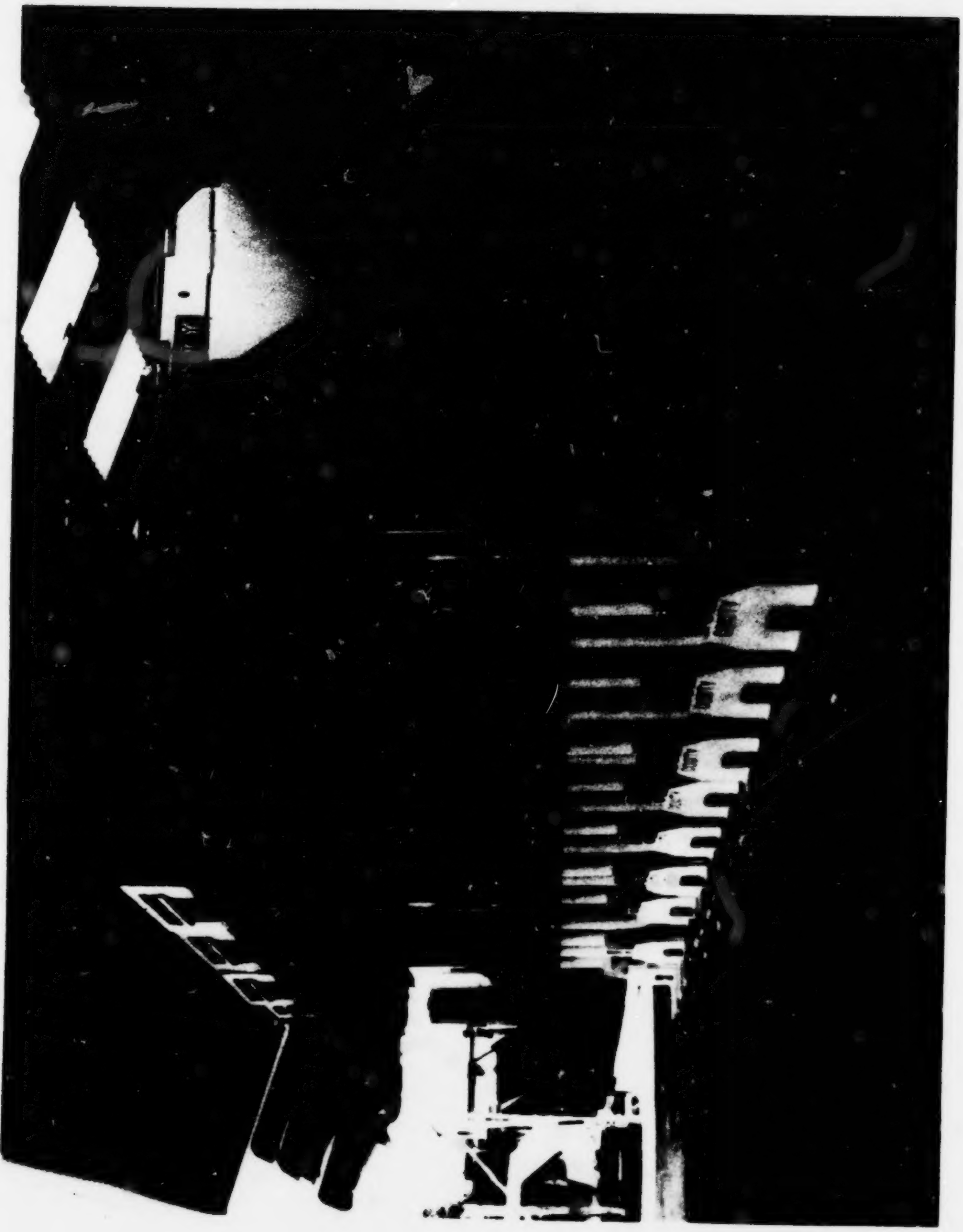
No. 98-4 MINE
SURFACE FACILITIES PLAN

NOV. 1982

FIG. 2-8







DESIGN PROCESS

- GENERAL DESIGN CONSIDERATIONS
- PARAMETERS FOR 9G-4 RESERVES
- SPECIFIC DESIGN FOR 9G-4

DESIGN CONSIDERATIONS

- RESERVES
- LAYOUT
- CONFIGURATION
- DEVELOPMENT
- VENTILATION
- TRANSPORTATION
- ELECTRICS
- WATER
- FIRST AID AND RESCUE

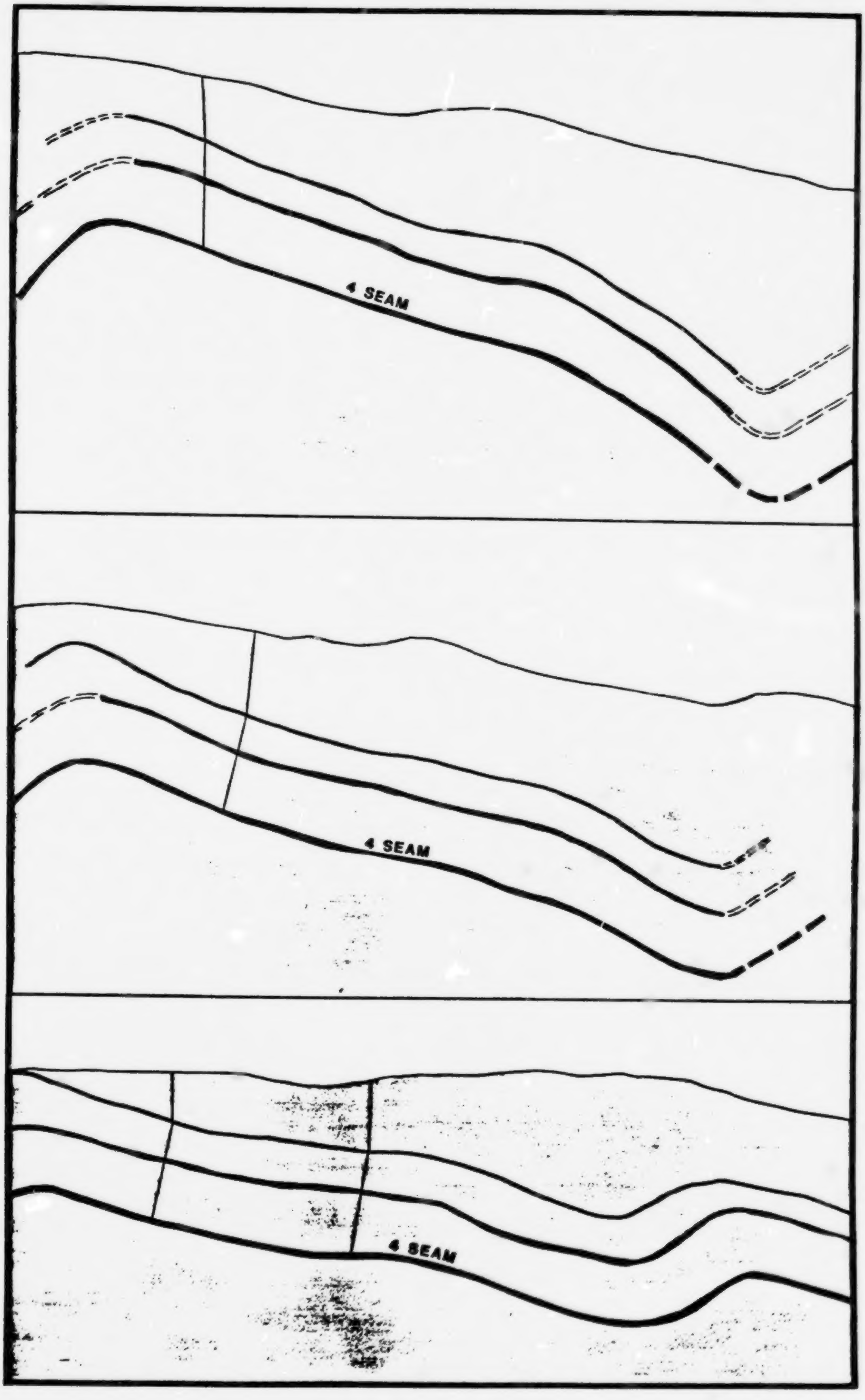
RESERVES AND PARAMETERS

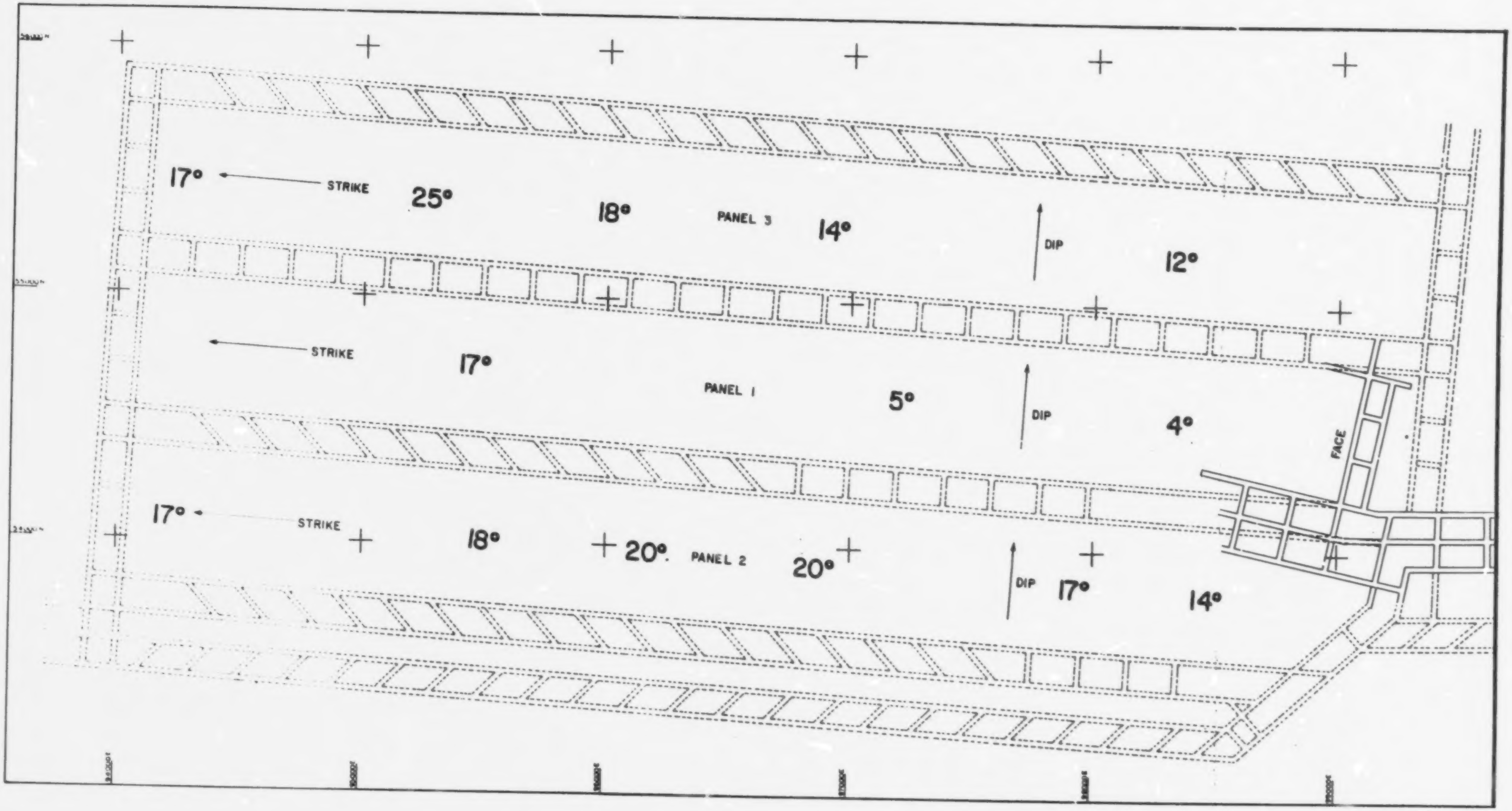
ASSUMPTIONS

- RESERVES IN 9G-4 DEDICATED TO LONGWALL
- NO DEVELOPMENT PENDING LONGWALL DECISION
- IF GO - LONGWALL DEVELOPMENT AND PRODUCTION WILL BE ONLY ACTIVITIES IN MINE
- MANPOWER AVAILABLE

GEOLOGY AND RESERVES

- 66 DRILL HOLES (72 HOLES PER SQ. MILE)
- MINE BOUNDARIES DETERMINED BY STRUCTURES
- TARGET #4 SEAM AV 20 - 22 FT. THICK
- SOFT COAL NEAR MIDDLE OF SEAM
- RECOVERABLE RESERVE APPROXIMATELY 4 MILLION TONS
- STRUCTURE GENTLY ROLLING DIPS TO NORTH 4° - 30°
- COMPETENT SEAM ROOF


4 SEAM
4 SEAM
4 SEAM


17°
STRIKE
25°
18°
PANEL 3
14°
DIP
12°
STRIKE
17°
PANEL 1
5°
DIP
4°
FACE
17°
STRIKE
18°
20°
PANEL 2
20°
DIP
17°
14°

GEOTECHNICS

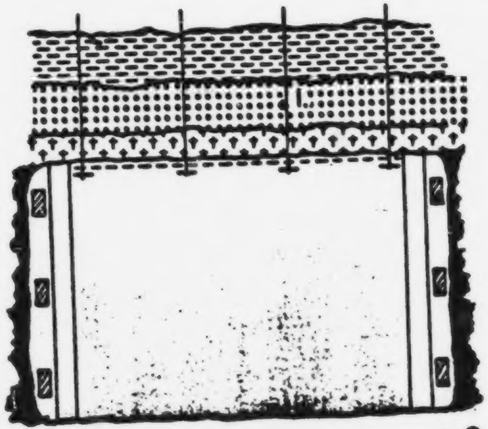
- DATA FROM 9G-4 AND 9A-4
- IMMEDIATE ROOF STRATA WILL CAVE SATISFACTORILY
- 1ST CAVE 8 - 10 FT. HIGH 4 - 10 FT. BEHIND SUPPORTS
- 2ND CAVE WILL FILL VOID
- CAVABLE STRATA 19 - 40 FT. THICK OVER TOTAL AREA
- SHEARED COAL BAND 12 - 14 FT. BELOW SEAM ROOF
- COAL STRENGTH ABOVE AND BELOW SOFT COAL ZONE ADEQUATE FOR ROOF SUPPORT OPERATION
- SUPPORT CAPACITY 450 TONS

MINING CONFIGURATION

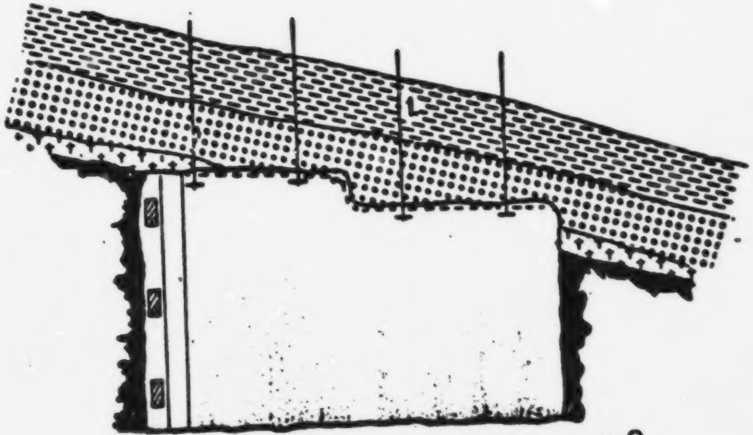
- THREE POSSIBLE SYSTEMS:
  - ADVANCE
  - RETREAT
  - ADVANCE/RETREAT
- LONGWALL RETREAT TO MINIMIZE RISK

DEVELOPMENT

- WHERE GRADIENT - 18° (PANEL 1), TWO ENTRY SYSTEM USING CURRENT TECHNIQUES
    - REDUCES CAPITAL EXPENDITURE
    - PROVIDES SATISFACTORY ADVANCE RATES
    - CAPITALIZES ON EXISTING EXPERTISE
    - PROVIDES GOOD ACCESS
- WHERE SEAM GRADIENTS + 18° (PANELS 2 AND 3) ALTERNATIVE SYSTEM

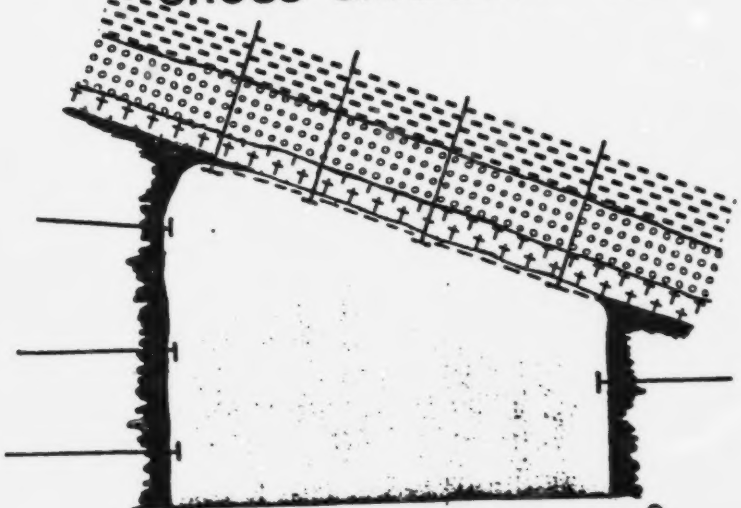


CROSS GRADIENT 0°



CROSS GRADIENT <18°

DEVELOPMENT CONFIGURATIONS



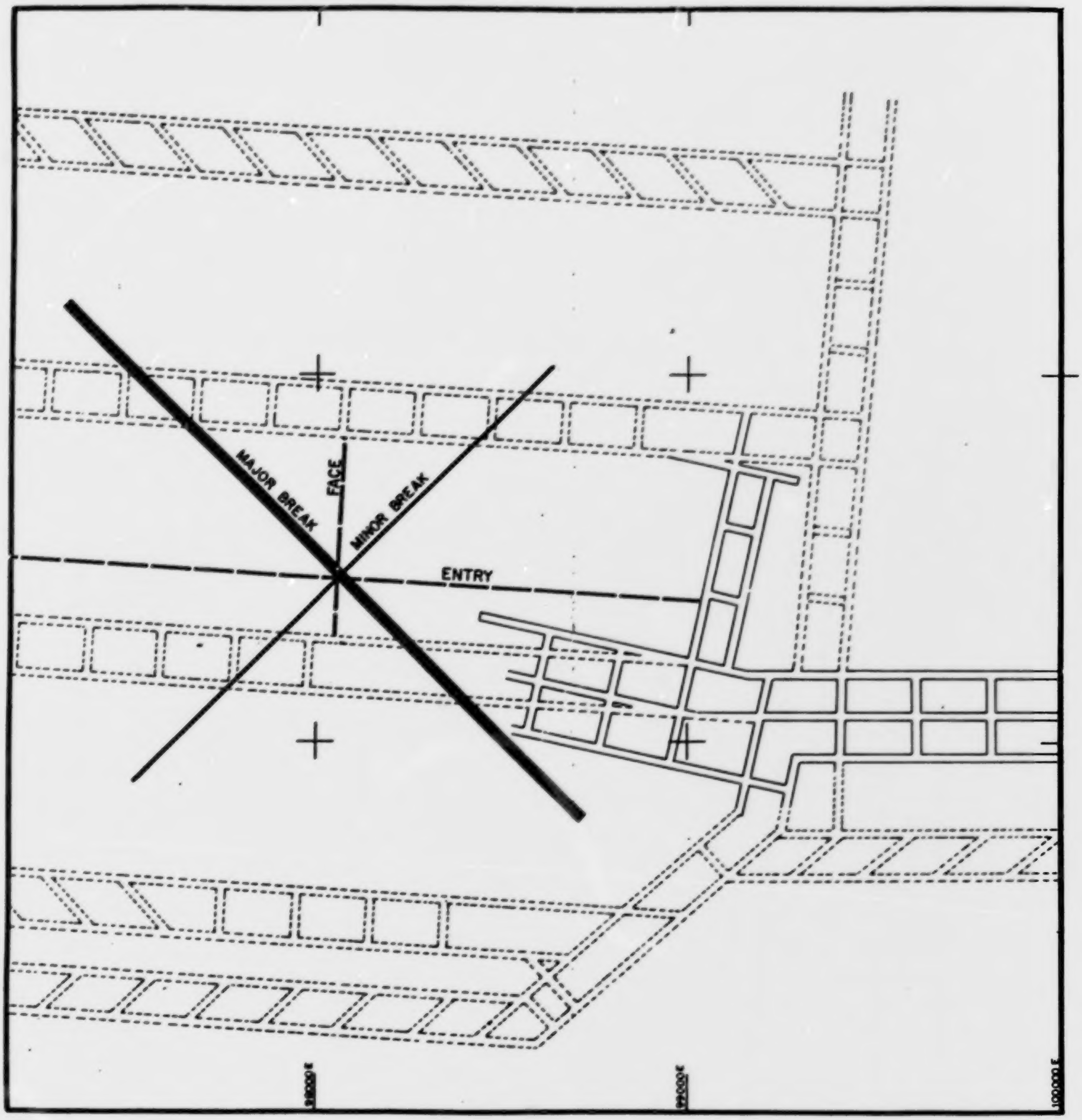
CROSS GRADIENT >18°

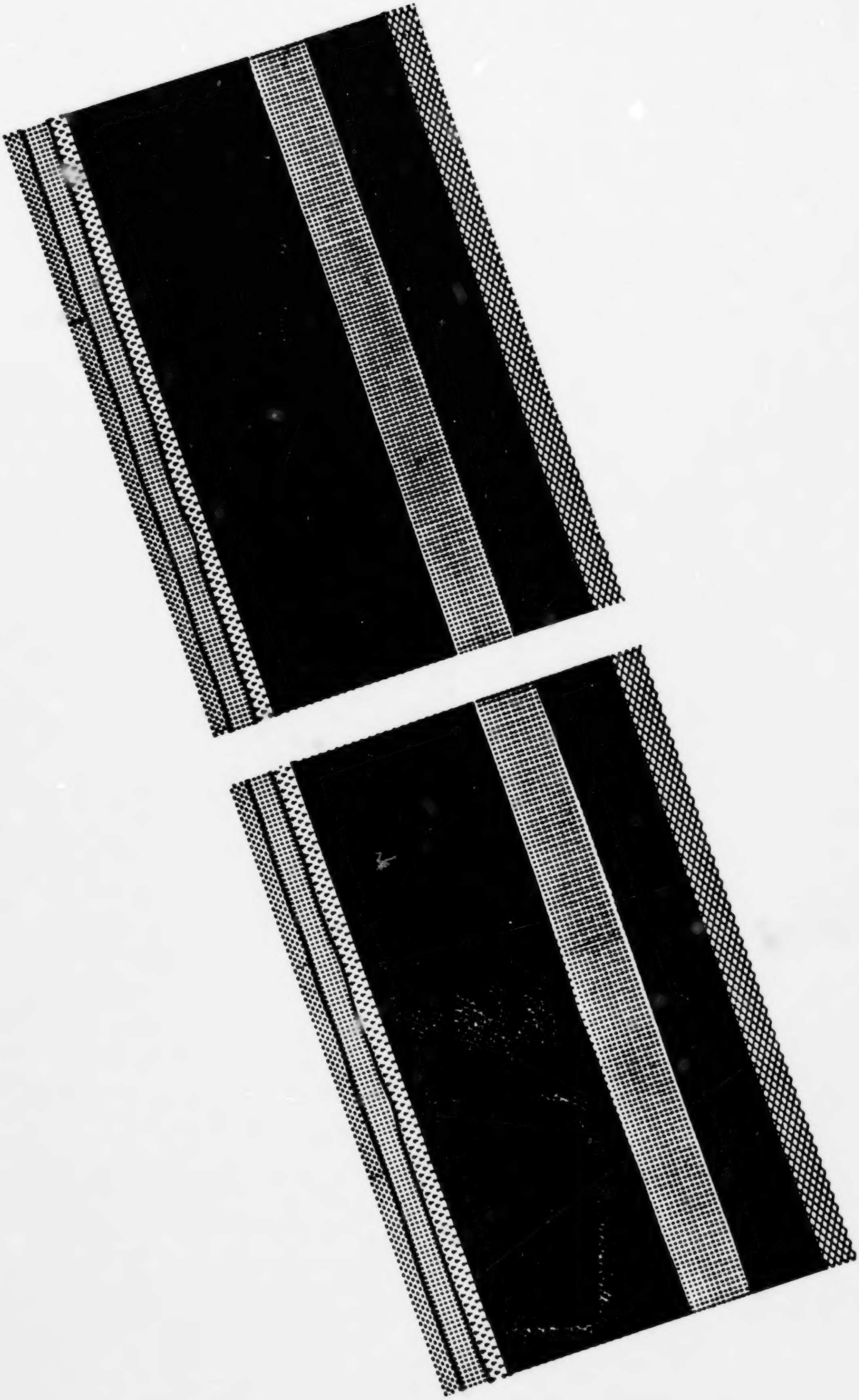
LONGWALL GEOMETRY

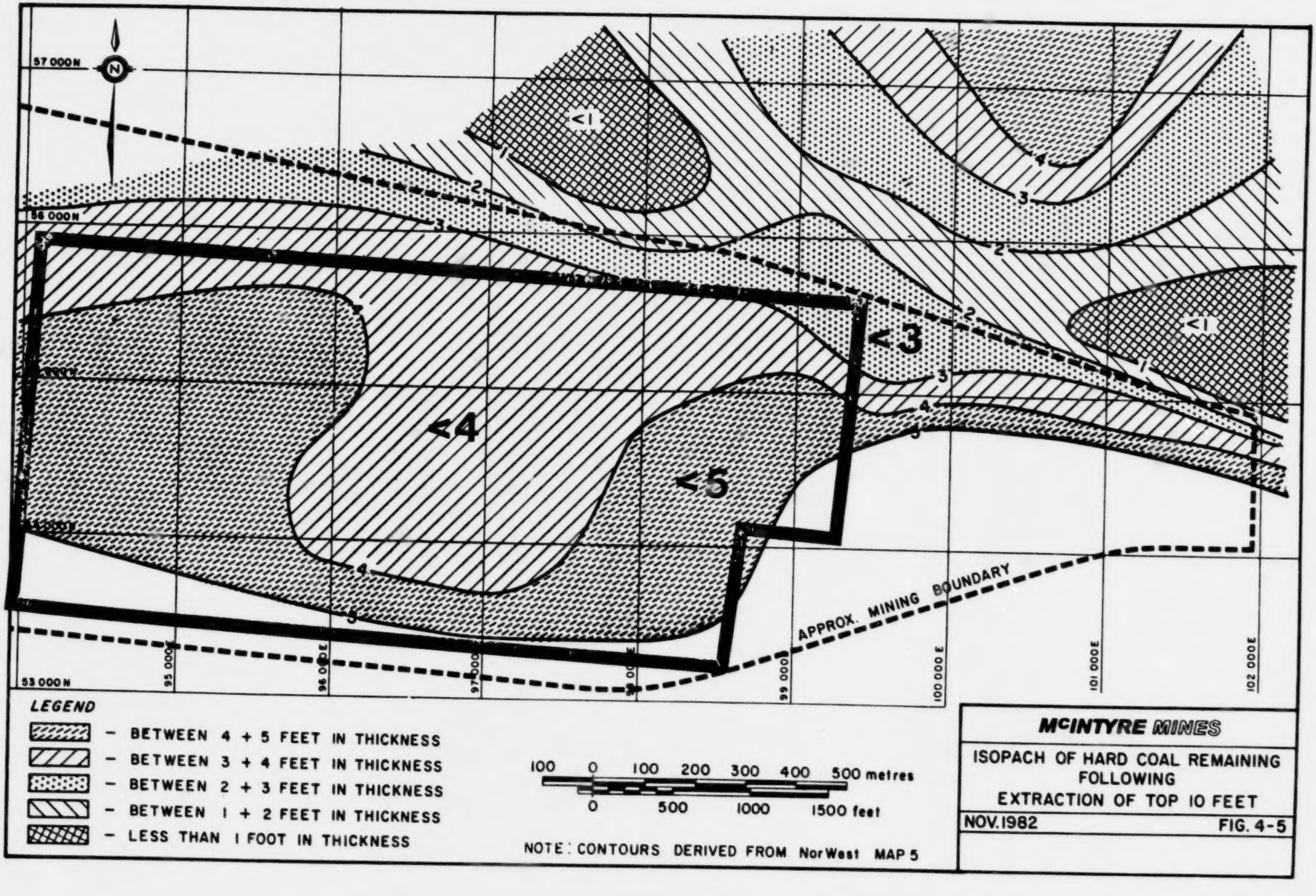
- ROADWAY AND FACE AT APPROX. 20° TO TECTONIC FRACTURES

- ROADWAYS IN TOP SECTION OF SEAM

- FACE LENGTH - 550 FT. TO ENSURE
  - CAVING
  - EMPLOY PROVEN EQUIPMENT
  - MAINTAIN POTENTIAL FOR #10 SEAM EXTRACTION
  - MAXIMIZE RESERVE RECOVERY


MAJOR BREAK
FACE
MINOR BREAK
ENTRY
98000E
99000E
100000E




57 000 N
56 000 N
53 000 N
95 000 E
96 000 E
97 000 E
98 000 E
99 000 E
100 000 E
101 000 E
102 000 E
N
<1
<1
<3
<4
<5
1
2
3
4
APPROX. MINING BOUNDARY
LEGEND
▨ - BETWEEN 4 + 5 FEET IN THICKNESS
▨ - BETWEEN 3 + 4 FEET IN THICKNESS
▨ - BETWEEN 2 + 3 FEET IN THICKNESS
▨ - BETWEEN 1 + 2 FEET IN THICKNESS
▨ - LESS THAN 1 FOOT IN THICKNESS
100 0 100 200 300 400 500 metres
0 500 1000 1500 feet
NOTE: CONTOURS DERIVED FROM NorWest MAP 5

McINTYRE MINES

ISOPACH OF HARD COAL REMAINING
FOLLOWING
EXTRACTION OF TOP 10 FEET

NOV. 1982

FIG. 4-5

PARAMETERS ADOPTED

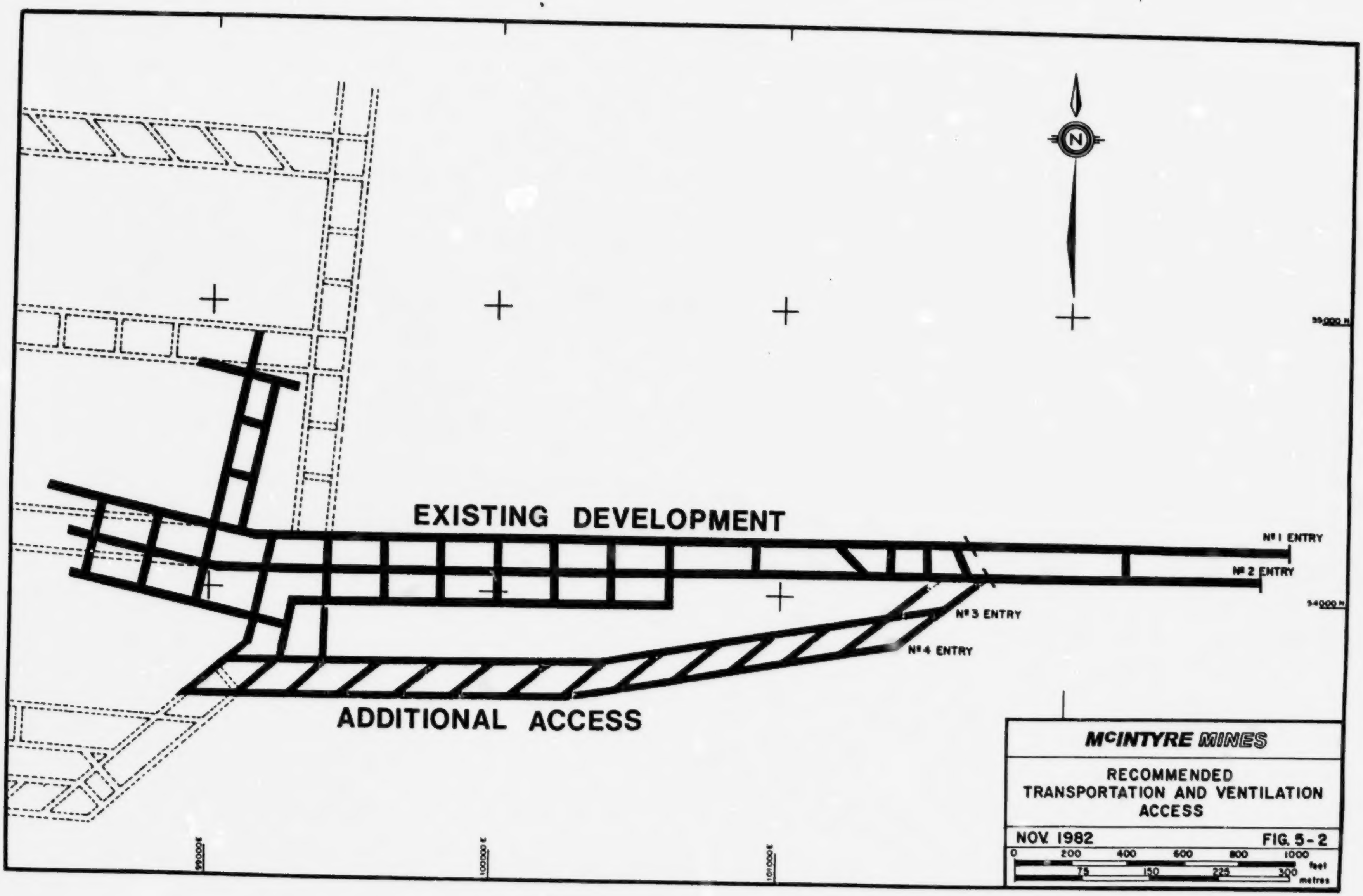
- TARGET AREA IN #4 SEAM PROVEN RESERVES
- TWO ENTRY DEVELOPMENT
- ALIGNED AT 20° TO TECTONIC FRACTURES
- RETREAT LONGWALL WITH TOTAL CAVING
- 550 FOOT FACE LENGTH
- 10 FOOT EXTRACTION
- 600 TON SUPPORTS TO SEAM ROOF ON COAL FLOOR

9G-4 MINE ACCESS

- CURRENT LAYOUT CONSTRAINS VENTILATION AND TRANSPORT
- NEW ROADWAYS IN COAL TO INTERSECT NO. 2 ENTRY
  - IMPROVED VENTILATION - PRESENT
    - FUTURE
  - TRANSPORT ROUTE SUITABLE FOR DIESEL VEHICLES

SPECIFIC DESIGN FOR 9G-4 MINE

- ACCESS
- PANEL LAYOUT
- SUBSIDENCE AND SEAM INTERACTION
- FACE EQUIPMENT
- HAULAGE AND TRANSPORT
- VENTILATION
- WATER SYSTEM
- ELECTRICAL SYSTEM


EXISTING DEVELOPMENT
ADDITIONAL ACCESS
Nº 1 ENTRY
Nº 2 ENTRY
Nº 3 ENTRY
Nº 4 ENTRY
N
35000 N
34000 N
99000 E
100000 E
101000 E
0
200
400
600
800
1000
feet
75
150
225
300
metres

McINTYRE MINES

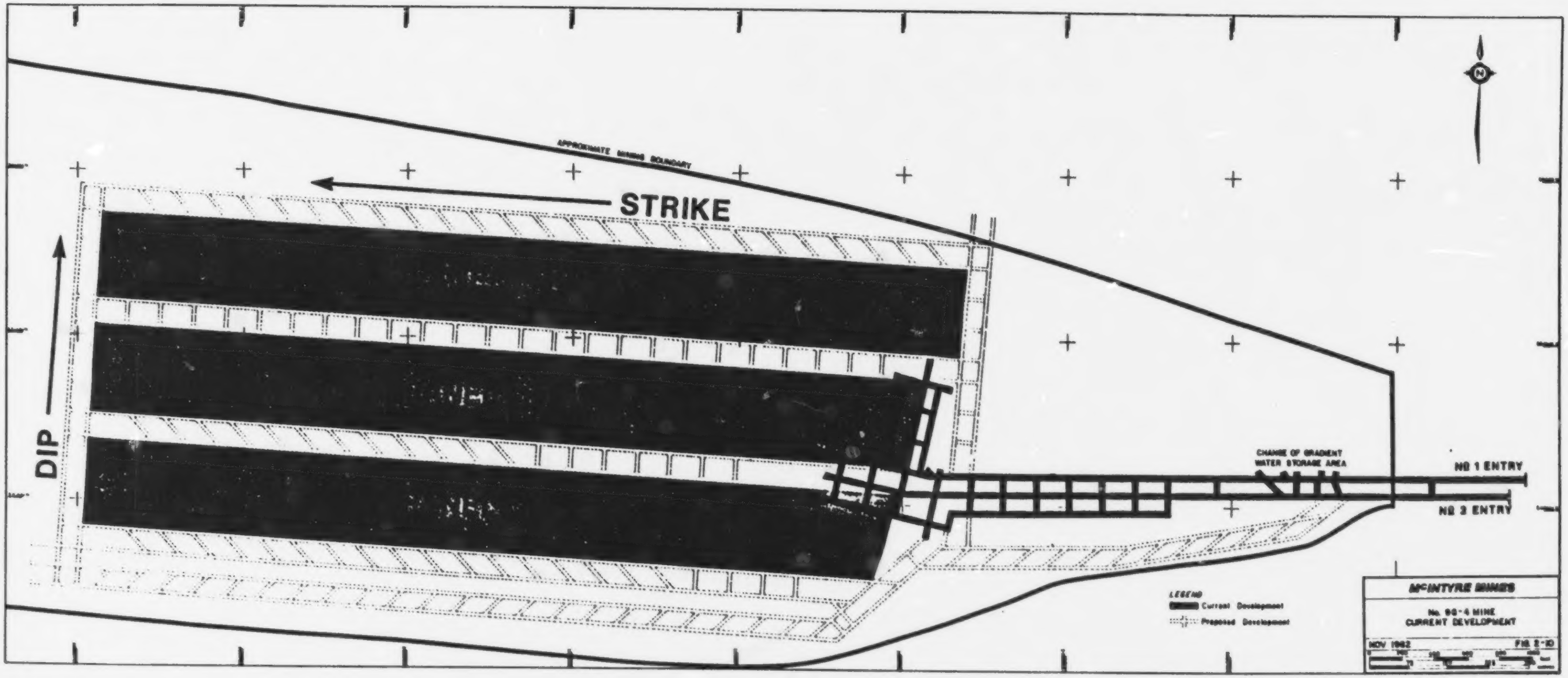
RECOMMENDED
TRANSPORTATION AND VENTILATION
ACCESS

NOV. 1982

FIG. 5-2

9G-4 PANEL LAYOUT

- ENTRIES ALONG STRIKE WITH FACE RETREATING ON DIP:
  - CONVENTIONAL DEVELOPMENT
  - LONG PANEL LIFE
  - SIMPLE VENTILATION
  - FACE RETREATS OUTBYE
  - GOOD WATER CONTROL
  - DIESEL VEHICLES CAN BE USED
- PILLARS 120 x 300 FT:
  - WITHSTAND PRESSURES DURING DEVELOPMENT AND FIRST EXTRACTION
  - CONTROLLED YIELD DURING SECOND EXTRACTION
- PANEL SEQUENCE
  - PANEL 1 LOW GRADIENTS (4° - 18°) AND SHORTEST TO ACCESS
  - PANEL 2 MODERATE GRADIENTS (14° - 20°)
  - PANEL 3 STEEPEST GRADIENTS (20°)

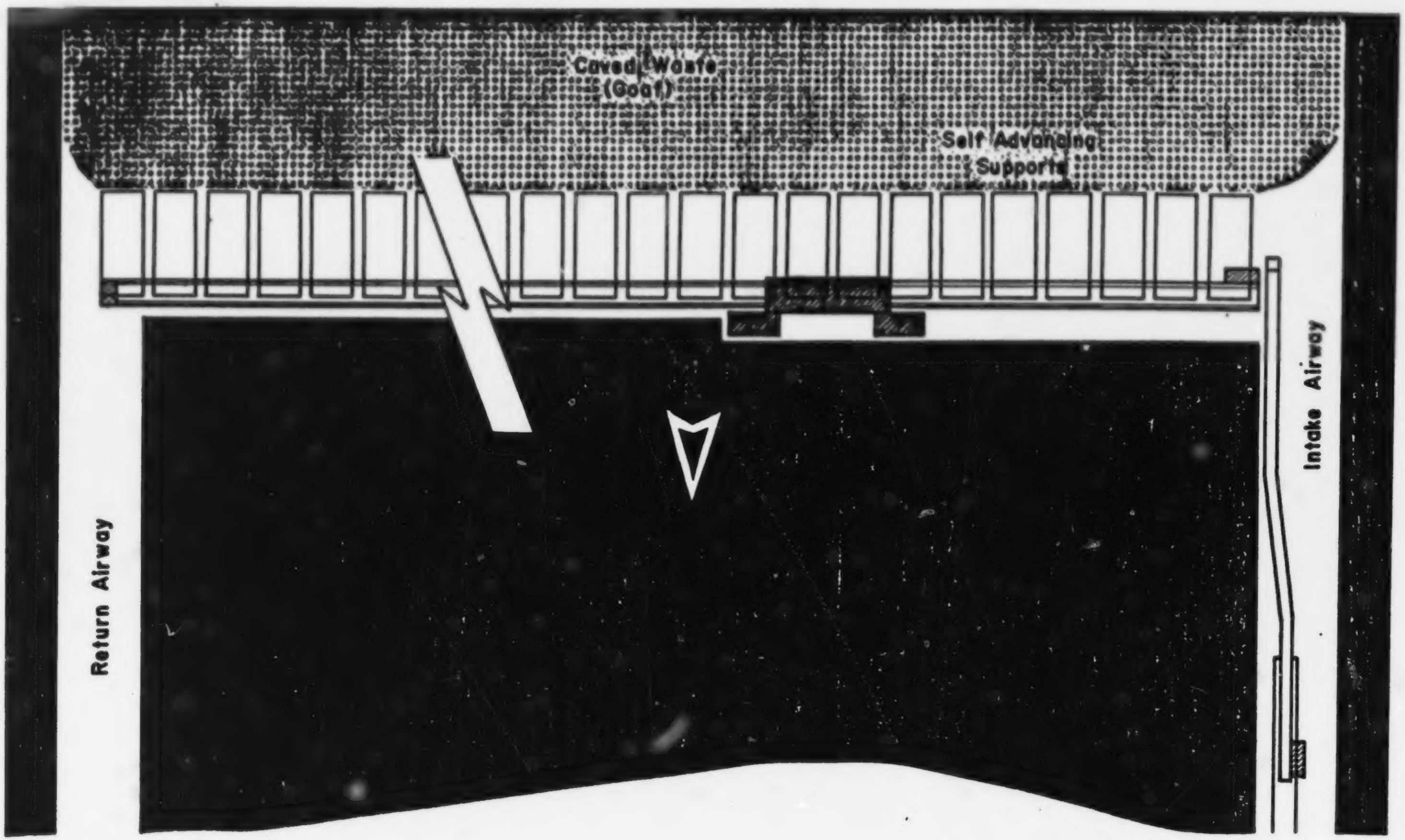

APPROXIMATE MINING BOUNDARY
STRIKE
DIP
CHANGE OF GRADIENT
WATER STORAGE AREA
NO 1 ENTRY
NO 2 ENTRY
LEGEND
Current Development
Proposed Development
McINTYRE MINES
No. 9G-4 MINE
CURRENT DEVELOPMENT
NOV 1982
FIG 2-10

9G-4 SUBSIDENCE AND SEAM INTERACTION

- LIMITED ROCKY MOUNTAIN DATA
- SURFACE SUBSIDENCE NOT A PROBLEM
- FULLY CAVED LONGWALL PRODUCES MOST MANAGEABLE SUBSIDENCE PROFILE
- SUBSIDENCE WILL BE REGULAR AND 550 FT #4 PANELS PERMIT FUTURE EXTRACTION IN DE-STRESSED AREAS OF #10 SEAM BY 400 - 450 FT LONGWALLS

FACE EQUIPMENT

- DEVELOP AND MINE AT LEAST TOP 10 FT
- 550 FT FACE LENGTH
- SHIELD OR CHOCK SHIELD SUPPORTS
- HEAVY DUTY AFC
- DOUBLE ENDED RANGING SHEARER
- LUMP BREAKERS
- SIMPLE ROADHEADS


Caved Waste
(Goaf)
Self Advancing
Supports
Return Airway
Intake Airway

McINTYRE MINES

TYPICAL FACE EQUIPMENT
LAYOUT

OCT. 1982

Scale: N.T.S.

9G-4 HAULAGE AND TRANSPORT

- COAL TRANSPORT BY CONVEYORS TO HANDLE MAX. RATE
- SUPPLIES BY DIESEL VEHICLES
  - LOW INITIAL CAPITAL COST
  - FLEXIBILITY
  - DIRECT TRANSPORT FROM SURFACE TO UNDERGROUND
- ALTERNATIVE SYSTEMS CONSIDERED FOR STEEPER PANEL 3
- MAN TRANSPORT BY BELT CONVEYORS
- SPECIAL VEHICLES LONGWALL EQUIPMENT
  AND ROAD MAINTENANCE

9G-4 VENTILATION

- EXHAUST MAIN VENTILATION
- FAN CAPACITY 200,000 CFM
- LONGWALL 60,000 CFM
- DEVELOPMENTS 40,000 CFM
- DUST CONTROLLED BY WATER SPRAYS AND VENTILATION
- METHANE AND SPONTANEOUS COMBUSTION NOT EXPECTED TO BE A PROBLEM

9G-4 MINE WATER SYSTEM

- ° WATER MAKE WITHIN TO 300 FT OF HEADINGS
- ° INFLOW USUALLY FROM ROOF
- ° UP TO 50 GPM OCCASIONALLY ENCOUNTERED
- ° NO WATER PROBLEMS ANTICIPATED ON LONGWALLS
  - AREA PRE-DRAINED BY DEVELOPMENT
  - WATER WILL FLOW TO WASTE AREA
- ° DEVELOPMENT WATER PUMPED TO DRIFT BOTTOM SUMP
- ° DUST AND FIREFIGHTING SYSTEM
  - 40,000 GALLONS STORED
  - AUXILIARY POWER SUPPLY FOR PUMPS

9G-4 ELECTRICAL SYSTEM

- ADEQUATE POWER SUPPLY AVAILABLE
- CABLES, COUPLERS AND SWITCHGEAR STANDARDIZED WHERE POSSIBLE
- NO VOLTAGE REGULATION PROBLEMS ANTICIPATED
- COMMUNICATION AND CONTROL SYSTEMS INTRINSICALLY SAFE
- ALL OTHER ELECTRICAL EQUIPMENT FLAMEPROOF
- DEVELOPMENT 550 VOLTS - LONGWALL 1100 VOLTS

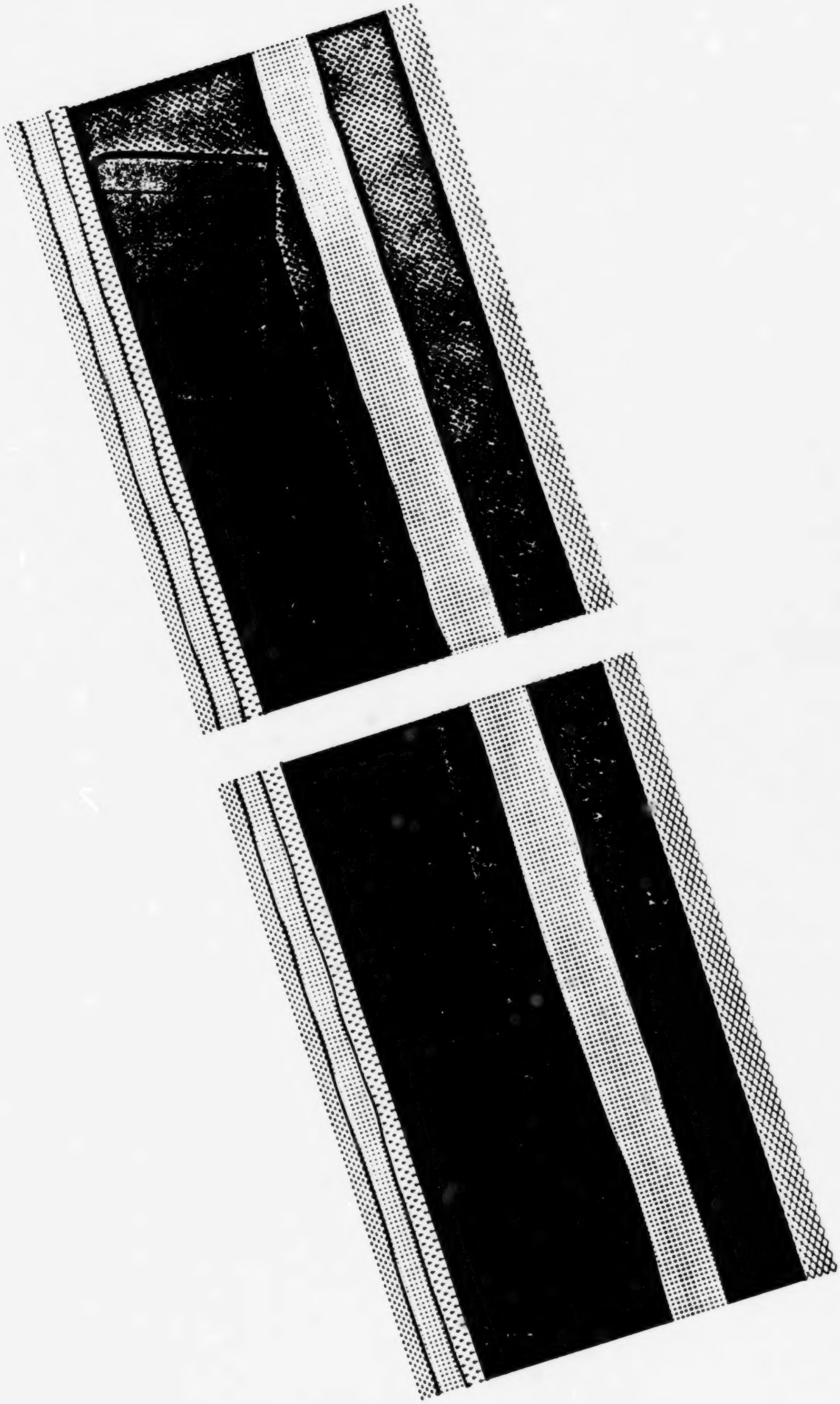
PART 2

9G-4 LONGWALL OPERATIONS

- DEVELOPMENT
- EQUIPMENT INSTALLATION
- LONGWALL PRODUCTION
- EQUIPMENT TRANSFER
- LONGWALL PERFORMANCE

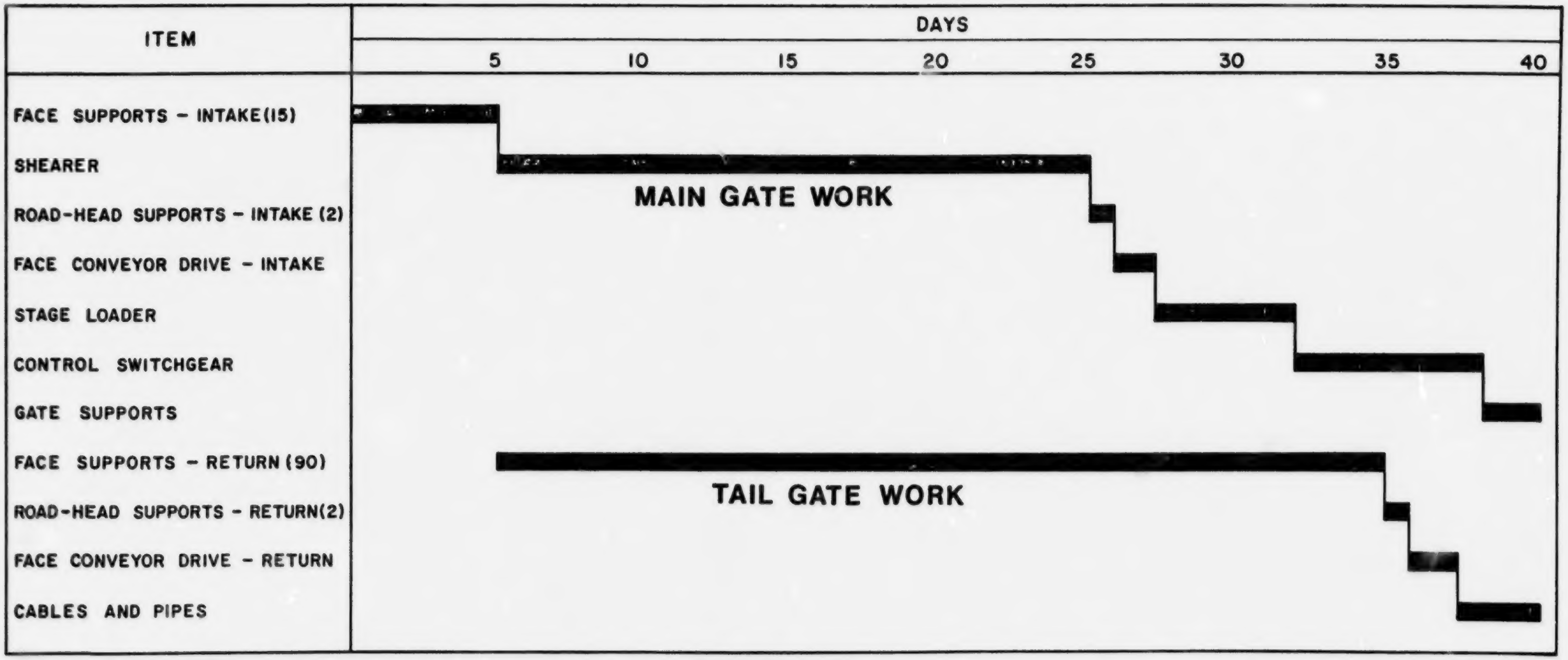
9G-4 DEVELOPMENT

- UP TO 18° TWIN ENTRY SYSTEM WITH EXISTING EQUIPMENT AND STEPPED ROOF IN HEADING
- ABOVE 18° PROFILE ROOF
- DEVELOPMENT PERFORMANCE ESTIMATED 100 FT PER DAY IN 3 SHIFTS AT 208 LTR/MC SHIFT = 625 LTR/DAY.



9G-4 EQUIPMENT INSTALLATION

- BEFORE EQUIPMENT DELIVERY:
  - PREPARE SURFACE AND UNDERGROUND STOCKING SITES
  - PREPARE TRANSPORT ROUTES AND EQUIPMENT
  - PREPARE SURFACE SITE FOR TRAINING
  - FINALIZE INSTALLATION PLAN AND SCHEDULE
  - BRIEF CREWS ON PROGRAM
- TRANSPORT AND INSTALL FACE EQUIPMENT IN ACCORDANCE WITH PLAN, SCHEDULE AND SUPPORT RULES



REQUIRES : 1/ HYDRAULIC POWER INSTALLED PRIOR TO FACE INSTALLATION
2/ INSTALLATION PROCEEDS ON CONTINUOUS BASIS

MᶜINTYRE MINES

LONGWALL EQUIPMENT
INSTALLATION SCHEDULE

NOV.1982 FIG. 6-4

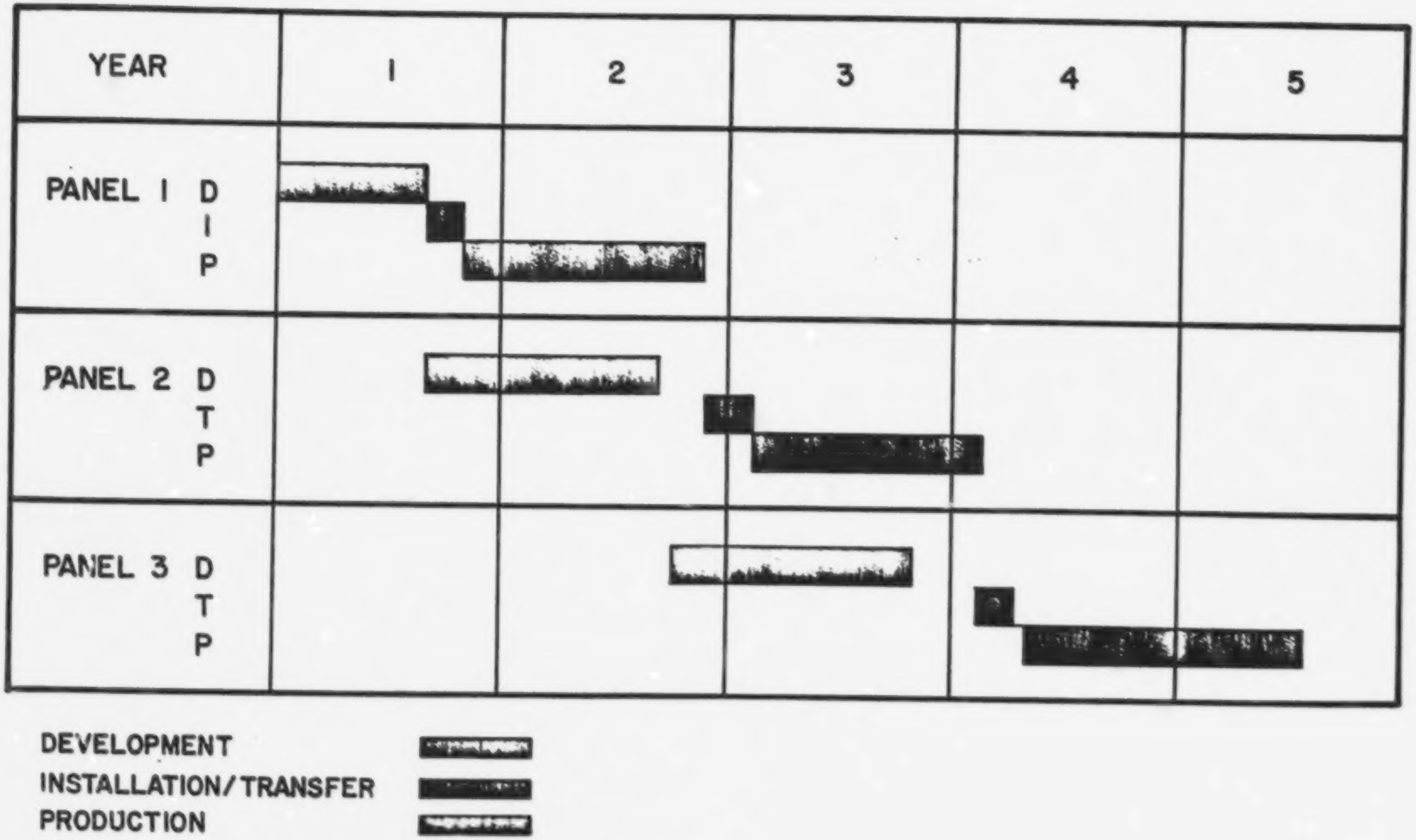
9G-4 LONGWALL PRODUCTION

- OPERATING PRACTICE:
  - STRAIGHT FACE LINE
  - MAINTENANCE TO SCHEDULE
  - EQUIPMENT FAULTS RECTIFIED IMMEDIATELY
  - PREPARE SNAKE AND CONVEYOR ADVANCE
  - PREPARE STAGE LOADER RETRACTION
  - REMOVE ALL EXCESS MATERIALS

TRANSFER OF EQUIPMENT

- CRITICAL OPERATION REQUIRES THOROUGH PREPARATION OF WORKED OUT AND REPLACEMENT FACE LINES
- ADDITIONAL SUPPORTS TO PROTECT FACE LINE
- PLANNED INTER-PANEL OVERHAUL/REPAIR WORK
- WORK CONTINUOUS SHIFTS TILL TRANSFER COMPLETE

SEQUENCE OF ACTIVITIES



PRODUCTION

(000'S/LONG TONS RAW COAL)

YEAR	DEVELOPMENT	LONGWALL	TOTAL
1	330	101	431
2	92	913	1005
3	86	948	1034
4	-	843	843
5*	-	494	494
TOTAL	508	3299	3807
	13%	87%	

* PART YEAR ONLY

PERFORMANCE STATISTICS (1)

(PANEL #1)

HEIGHT (FEET)	10
FACE LENGTH (FEET)	550
WEB DEPTH (FEET)	2.25
SHIFTS/DAY	3
AWT/SHIFT (MINS)	390
MANSHIFTS/DAY - FACE	56
MANSHIFTS/DAY - TOTAL	168 (INCL. OT)
TONS/SHEAR (RAW)	476

PERFORMANCE STATISTICS (2)

(PANEL #1)

	MACHINE CAPACITY	PROJECTED SHORT TERM PERFORMANCE	PROJECTED LONG TERM PERFORMANCE
CYCLES/DAY	13.8	11.5	9.2
OUTPUT/DAY (LTR)	6569	5454	4370

DEMONSTRATION PRODUCTIVITY
(RAW COAL BASIS)

	TONS (000'S)	MANSHIFTS (000'S)	TONS/MS
DEVELOPMENT	508	31	16
LONGWALL	3299	62	53
OTHER	-	59	-
TOTAL	3807	152	25

EQUIPMENT TENDERS

- SPECIFICATION BASED ON CURRENT TECHNOLOGY:
  - SYSTEMS CAN BE EVALUATED AT OTHER MINES
  - OPERATING EXPERIENCE CAN BE ASSIMILATED
  - MINIMAL MALFUNCTION POTENTIAL
  - LOWEST CAPITAL COST
- FIVE TENDERS NOT FULLY ALIGNED WITH ENQUIRY
- OFFERED WIDE RANGE OF OPTIONS
- TWO SUPPORT SYSTEMS LESS ACCEPTABLE THAN OTHERS
- CAPITAL COST ESTIMATED BY COMBINING TENDER DATA = $12.5 MILLION

PROJECT MANAGEMENT

- OBJECTIVE TO DEMONSTRATE:
  - IMPROVED SAFETY
  - IMPROVED RESERVE RECOVERY
  - ECONOMIC VIABILITY
- OPPORTUNITY FOR:
  - RESEARCH
  - COLLECTION AND DISSEMINATION OF DATA
  - "HANDS ON" TRAINING

PROJECT MANAGEMENT

- COMPLEX AND CHALLENGING
  - LOCATED AT EXISTING MINE
  - LONGWALL PRODUCTION HIGH PERCENTAGE OF TOTAL OUTPUT
  - MINING STATUTES ASSIGN SAFETY RESPONSIBILITY
  - RESEARCH NEEDS
- NEED RAPID SOLUTION OF PROBLEMS DURING DEMONSTRATION

PROJECT MANAGEMENT

PROJECT TEAM

- SMALL IN NUMBER
- EXPERIENCED IN LONGWALL
- CLEARLY DEFINED ROLES
- COORDINATE MINING, REGULATORY AND RESEARCH REQUIREMENTS
- GUIDANCE FROM STEERING COMMITTEE

PROPOSED STEERING COMMITTEE

CHAIRMAN - CANMET REPRESENTATIVE

MEMBERS - DEPARTMENT OF OCCUPATIONAL HEALTH AND SAFETY
- ENERGY RESOURCES CONSERVATION BOARD
- DEPARTMENT OF ENERGY, MINES & NATURAL RESOURCES
- COAL MINING RESEARCH CENTRE
- COAL ASSOCIATION OF CANADA, RESEARCH & DEVELOPMENT
- VP/GENERAL MANAGER, SMOKY RIVER COAL LIMITED

EX OFFICIO - MANAGER UNDERGROUND MINES, SMOKY RIVER COAL LIMITED
- PROJECT MANAGER, CANMET

TERMS OF REFERENCE - STEERING COMMITTEE

- MONITOR THE PROGRESS OF THE LONGWALL TRIAL
- PROVIDE PERIODIC AND FINAL ASSESSMENT OF THE PROJECT
- COLLATE AND DISSEMINATE INFORMATION ON THE PROJECT
- APPROVE AND CO-ORDINATE ADDITIONAL ON-SITE RESEARCH

SECONDARY RESEARCH

- POTENTIAL RESEARCH AREAS
  - RAPID ROADWAY DRIVAGE
  - CONVERGENCE AND SUBSIDENCE
  - REMOTE MONITORING AND CONTROL
  - METHANE
  - DUST CONTROL
  - ROOF SUPPORT SYSTEMS
  - HEALTH AND ENVIRONMENT MONITORING
- 9G-4 RESERVE CONFIGURATION AND MINING SEQUENCE WILL ALLOW RAPID ASSESSMENT OF FACTOR RELATED EVENTS

TRAINING

° THREE TYPES OF TRAINING:

  - SUPERVISORY
  - OPERATING
  - MAINTENANCE

° PROGRAM WILL BE PHASED

  - VISIT MINES AND MANUFACTURERS
  - SITE TRAINING BEFORE INSTALLATION
  - TRAINING DURING INSTALLATION/OPERATION

° PROGRAM WILL ENSURE PERSONNEL UNDERSTAND:

  - PROJECT OBJECTIVES
  - PERSONAL CONTRIBUTION
  - MINING SYSTEMS
  - OPERATING CHARACTERISTICS
  - SAFETY REQUIREMENTS

CAPITAL COSTS

	$ MILLIONS	
	5-YEAR	10-YEAR
DEVELOPMENT EQUIPMENT	4.7	6.2
LONGWALL EQUIPMENT	12.5	12.5
REPLACEMENT EQUIPMENT	2.0	6.0
EXPLORATION	0	1.5
TOTAL	19.2	26.2
	====	====

DIRECT MINING COST

- TO MINE-MOUTH STOCKPILE
- INCLUDES DEVELOPMENT, LONGWALL AND ALL MINE SERVICES

$/RAW TON	YEAR				
	1	2	3	4	5-10
DEMONSTRATION PERIOD	33.53	13.46	12.96	13.53	11.64
EXTENDED OPERATION	33.53	13.46	12.96	14.41	14.15

CASH FLOW ANALYSIS

● ASSUMED PRICE	$87.50 FOB
● EQUIPMENT EXPENDITURES	YEAR 1
● 5-YEAR NET PRESENT VALUE	$10.2 MILLION
● 10-YEAR NET PRESENT VALUE	$18.4 MILLION
● SENSITIVE TO PRODUCTION, PRICE VARIANCES	

PROCUREMENT FINANCING

OPTION 1: 5% WITH ORDER, 10% UPON SHIPMENT, 85% IN 10 EQUAL SEMI-ANNUAL PAYMENTS. INTEREST RATE = 12.15%.

OPTION 2: 10% WITH ORDER, 10% UPON SHIPMENT, 80% IN 10 EQUAL SEMI-ANNUAL PAYMENTS. INTEREST RATE 9%. NOTE FINANCIAL ARRANGEMENTS COVER MATERIALS MANUFACTURED IN COUNTRY OF ORIGIN. REQUEST PAYMENT IN DESIGNATED CURRENCY.

OPTION 3: BASED ON 5-YEAR LEASE OPTIONS PROVIDED. TOTAL EQUIPMENT COST RECOVERED IN THIS PERIOD AND EQUIPMENT CAN THEN BE PURCHASED OUTRIGHT FOR $1.

RISKS

- PRESENT STATUS OF DEVELOPMENT MINIMIZES RISK BUT PROJECT IS UNIQUE
- LONGWALL REPLACES ALL OTHER UNDERGROUND PRODUCTION AND FAILURE WOULD MAKE QUOTAS DIFFICULT TO MEET
- LONGWALL DEVELOPMENTS NOT READILY ADAPTABLE TO R & P
- RISKS NOT QUANTIFIABLE UNTIL AFTER DEMONSTRATION
- COST SHARING COULD REDUCE RISK TO OPERATOR

TECHNICAL FINDINGS

- LONGWALL DEMONSTRATION IS TECHNICALLY FEASIBLE
- LONGWALL CAN BE READILY IMPLEMENTED AT NO. 9G-4
- DEVELOPMENT AND PRODUCTION CAN BE MAINTAINED IN BALANCE
- EQUIPMENT SUPPLIERS WILL GIVE PERFORMANCE GUARANTEES
- EQUIPMENT COULD CONTINUE IN USE IN NO. 9G-4 AFTER DEMONSTRATION
- PRODUCTIVITY TO MINE-MOUTH STOCKPILE ESTIMATED 26 LTR/MS

ECONOMIC FINDINGS

- LONGWALL EQUIPMENT COST WILL BE $12.5 MILLION
- PRODUCTION COST AT MINE-MOUTH ESTIMATED

	YEAR	COST ($/RAW TON)
-	1	$33.53
-	2	$13.46
-	3	$12.96
-	4	$13.53
-	5	$11.64

- DEMONSTRATION PROJECT HAS NPV OF $10.2 MILLION DISCOUNTED AT 10%
- EXTENDED OPERATION IMPROVES ECONOMIC PICTURE HAS NPV $18.4 MILLION

RECOMMENDATIONS

- CANMET SHOULD PARTICIPATE IN J.V. DEMONSTRATION PROJECT IN WESTERN CANADA
- CANMET AND OTHER AGENCIES SHOULD INVEST CAPITAL UP FRONT TO BE RECOUPED IF DEMONSTRATION SUCCESSFUL
- A STEERING COMMITTEE AND PROJECT MANAGEMENT GROUP SHOULD COORDINATE DEMONSTRATION
- IF DEMONSTRATION HELD AT LOCATION OTHER THAN 9G-4 WOULD NEED SITE SPECIFIC STUDIES AND A MARKET FOR THE PRODUCTION

SPECIAL LONGWALL APPLICATIONS

BY JOHN P.L. BACHARACH, P.ENG.
CONSULTING MINING ENGINEER
CALGARY, ALBERTA, CANADA

JPLB/SDS

NOVEMBER 1983

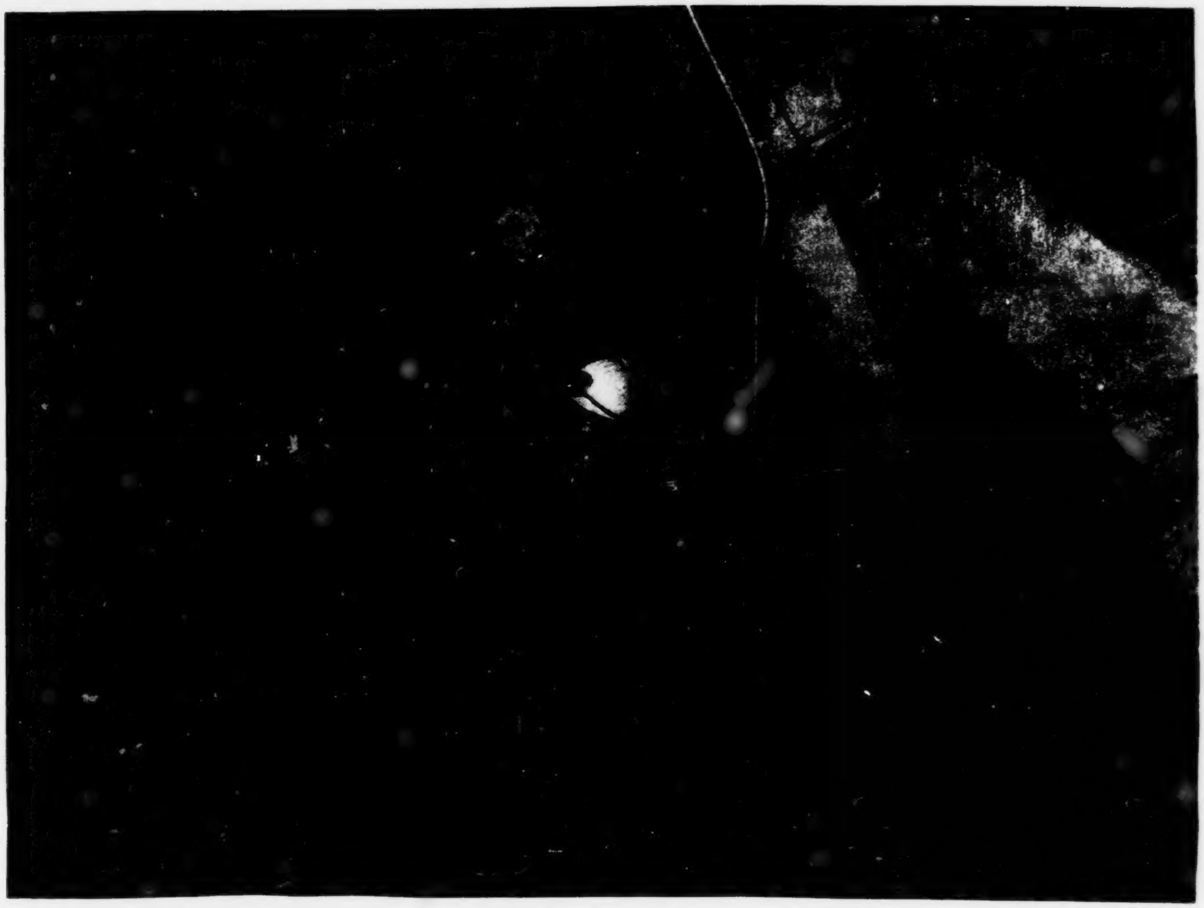
SPECIAL LONGWALL APPLICATIONS

INTRODUCTION

This section addresses applications of longwalling where gradients are more severe and seams are thicker or thinner than those discussed earlier. Such applications indicate the wide range of conditions that could be considered for longwall.

Information on the installation described has been obtained from site visits and/or published material. In some examples elements from more than one individual wall have been composited to illustrate typical circumstances.

THICK SEAM	+ 10 FT
MEDIUM SEAM	5 - 10 FT
THIN SEAM	- 5 FT
STEEP SEAM	+ 30°



J.P.L. Bacharach - 3

1 THICK - SINGLE LIFT ALONG STRIKE

2 THICK - MULTI-LIFT

3 THICK - WITH SECONDARY RECOVERY BY CAVING

4 THIN - ALONG STRIKE

5 STEEP - ALONG STRIKE

6 STEEP - TO THE RISE

1.1 THICK SEAM - SINGLE LIFT ALONG STRIKE

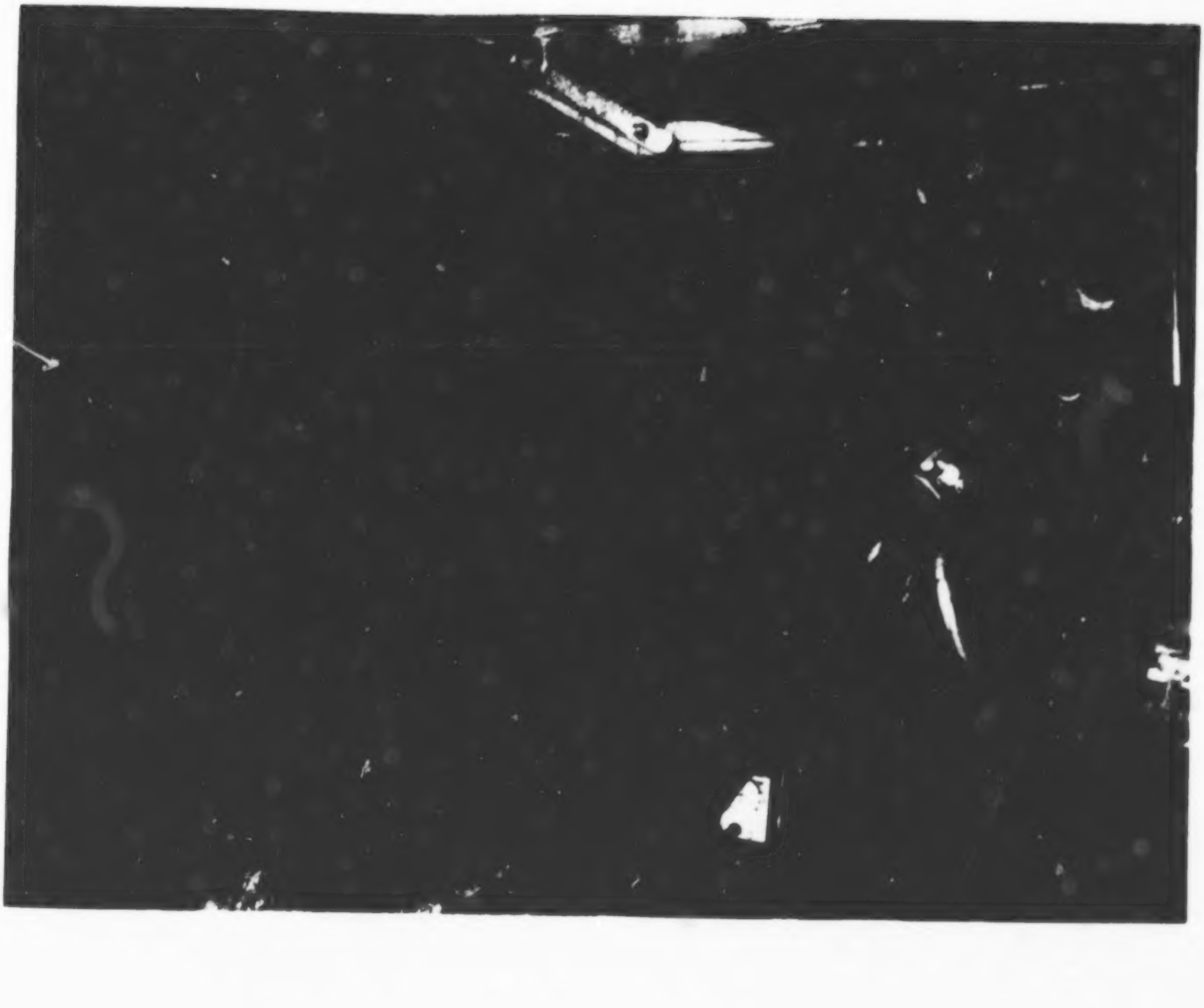
- EXTENSION OF MEDIUM SEAM TECHNOLOGY
- HEAVIER SUPPORTS
- MORE POWERFUL POWER LOADER
- INCREASED COAL CLEARANCE CAPACITY

1.2 THICK SEAM - SINGLE LIFT ALONG STRIKE

- SLOUGHING
- TRAVELWAY SAFETY
- SHEARER POWER
- SHEARER STABILITY
- CONVEYOR CAPACITY
- LUMP CONTROL
- SUPPORT TRANSFER

1.3 Carbon County Coal Company, Wyoming, U.S.A.

LAYOUT	Retreat - 2/3 Entry Development
SEAM THICKNESS	16 Ft - 24 Ft
MINING HEIGHT	12 Ft (Increase Planned)
GRADIENT	12% Along Face
FACE LENGTH	400 Ft
PANEL LENGTH	2100 Ft to 7500 Ft
SUPPORTS	KB/NMS 500 ton, 2 leg shields, forepoles, Face Sprags, Elevated Walkway
CONVEYOR	Hand B
POWER LOADER	300 KW Eickhoff, DERDS 80" Drums, Chainless Haulage, Radio Control
PERFORMANCE	Approximately 1500 - 2000 Tons/Shift



2.1 THICK SEAM - MULTI-LIFT

- SUCCESSIVE APPLICATION OF MEDIUM OR THICK SEAM TECHNOLOGY

- COMPLEXITY ARISES FROM INTER-RELATIONSHIP BETWEEN SUCCESSIVE LIFTS

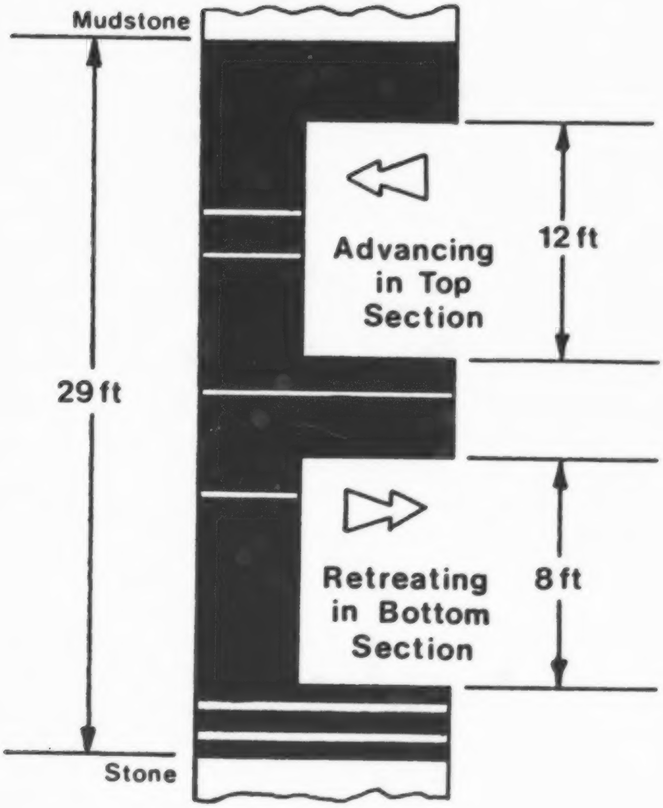
- OVERALL PRODUCTIVITY GENERALLY LOWER THAN SINGLE LIFT, BUT RESOURCE RECOVERY BETTER

2.2 THICK SEAM - MULTI-LIFT

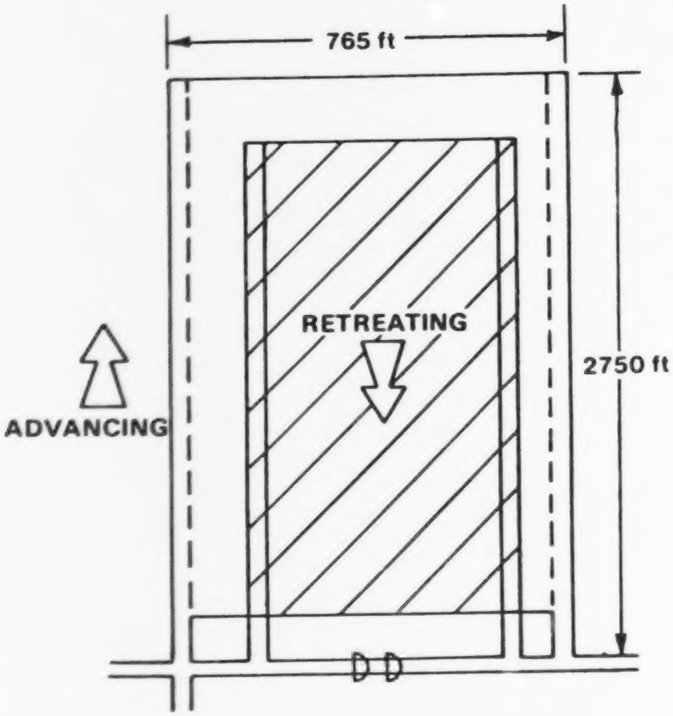
- INTERACTION
- CONSOLIDATION/INTERFACES
- SPONTANEOUS COMBUSTION
- HEIGHT OF SLICES

2.3 DAW MILL MINE, NCB SOUTH MIDLANDS, U.K.

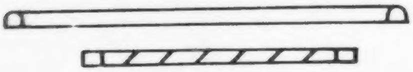
LAYOUT	ADVANCING (UPPER SLICE)
SEAM THICKNESS	25 FT
MINING HEIGHT	12 FT
GRADIENT	1 IN 11 ALONG FACE
FACE LENGTH	765 FT
PANEL LENGTH	2750 FT
SUPPORTS	DOWTY 4/450 TONNES CHOCK SHIELDS
CONVEYOR	UMM 38", 2 x 225 KW
POWER LOADER	1 AM500 SERDS 24" x 72" 1 AM500 DERDS
PERFORMANCE	2150 CLEAN TONNES/DAY AT 27 TONNES OMS (INCLUDES ENTRY DEMONSTRATION)


Mudstone
Advancing
in Top
Section
12 ft
29 ft
Retreating
in Bottom
Section
8 ft
Stone

SECTION


765 ft
RETREATING
2750 ft
ADVANCING

PLAN



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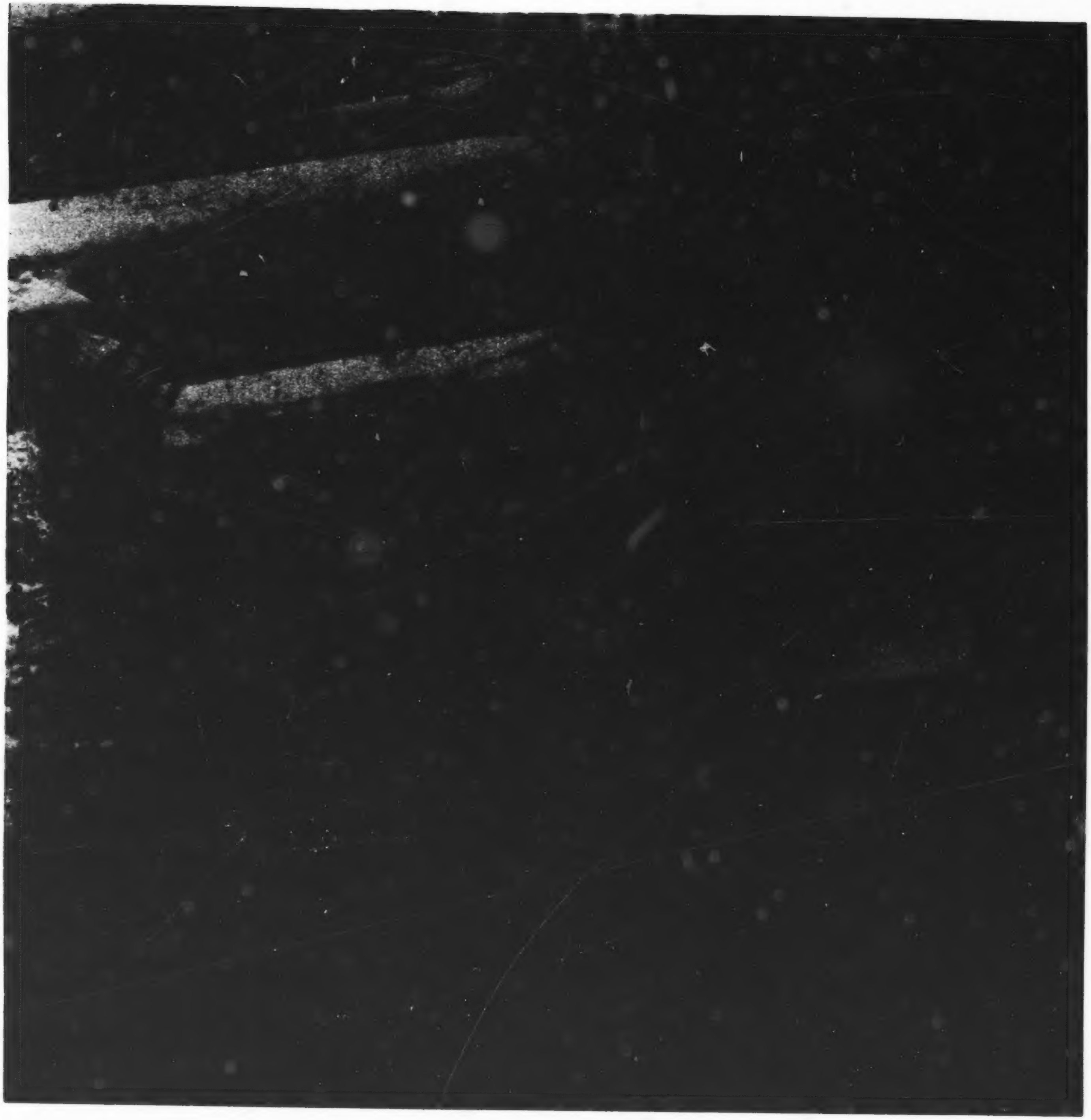
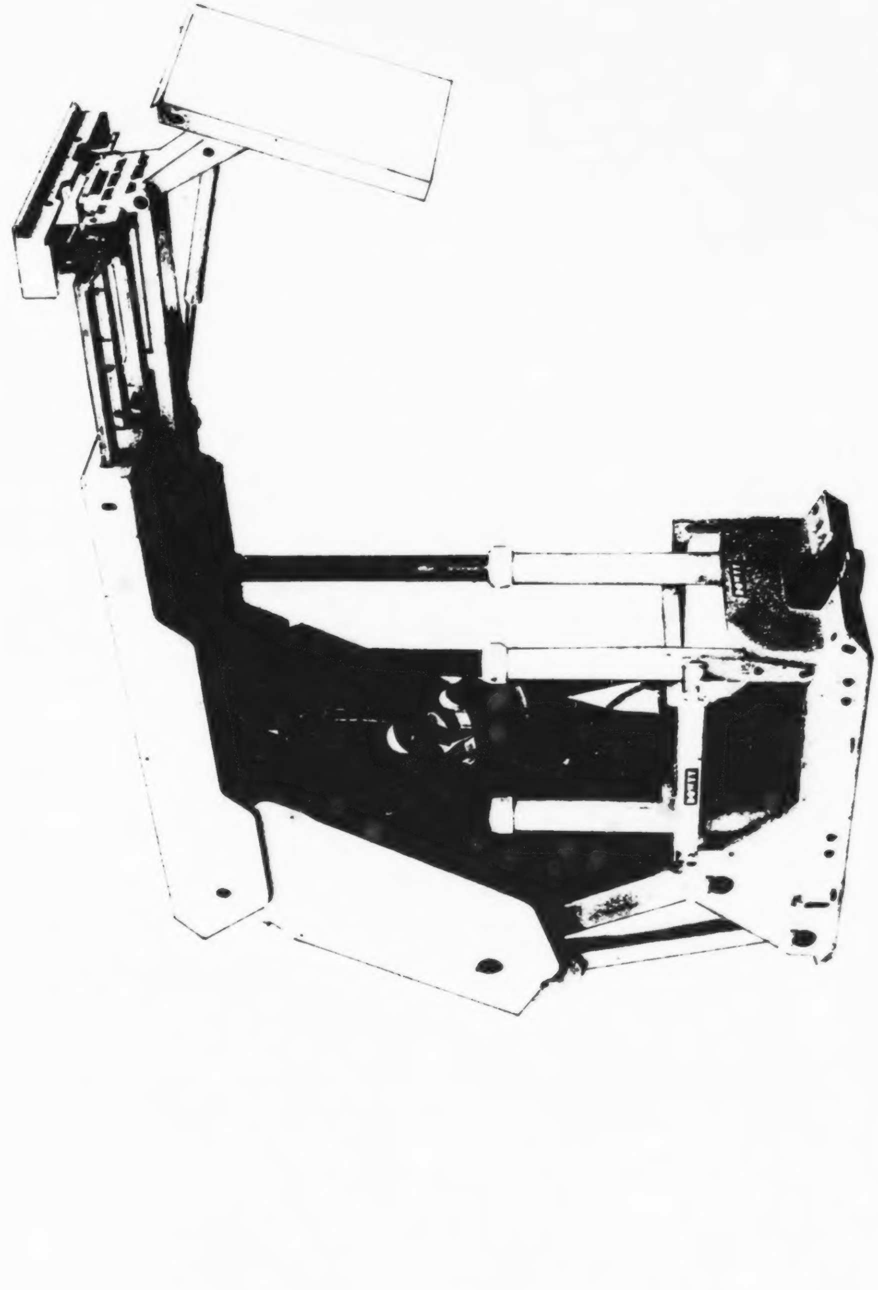
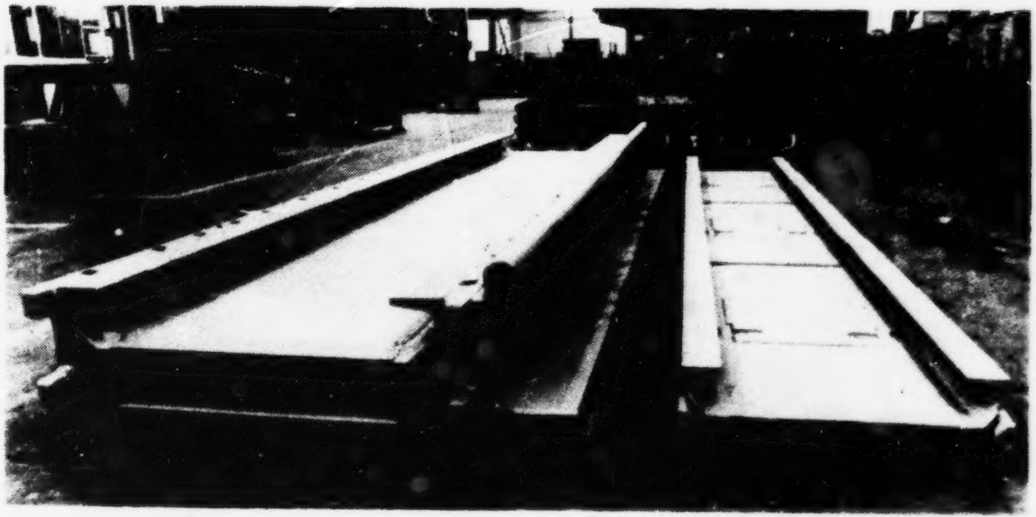






971mm x 277mm
26mm TWIN OUTBOARD
CHAIN

764mm x 222mm
22mm TWIN OUTBOARD
CHAIN

3.1 THICK - WITH SECONDARY RECOVERY BY CAVING

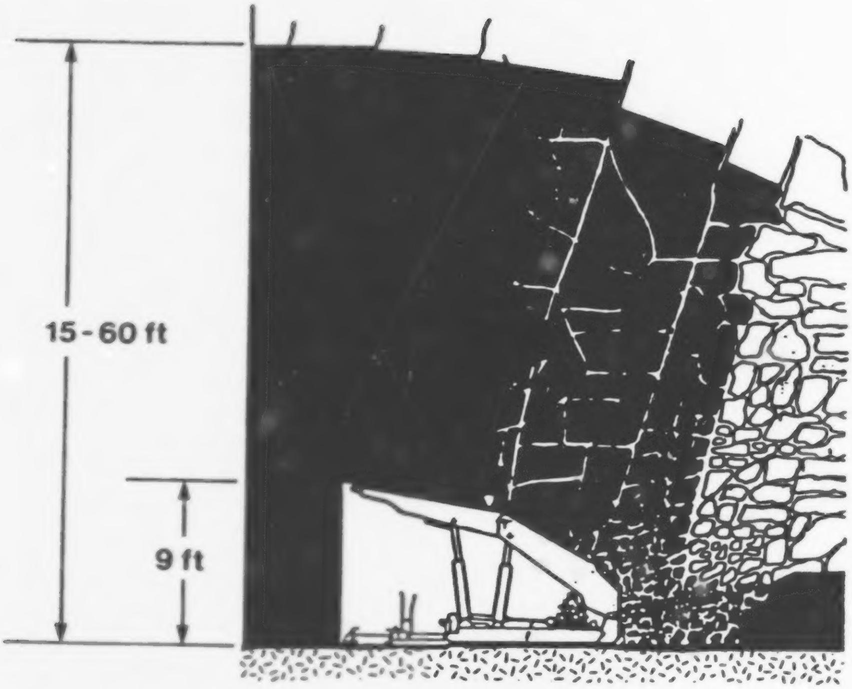
- BOTTOM SLICE LIKE CONVENTIONAL WALL
- RECOVER ROOF COAL FROM CAVED MATERIAL
- COMBINATION OF TWO EXTRACTIONS ADDS COMPLEXITY
- RELEASE OF CAVED COAL NOT FULLY CONTROLLABLE
- PRODUCTIVITY LOWER THAN SINGLE LIFT BUT IMPROVES RESOURCE RECOVERY AND IS FLEXIBLE IN SEAMS OF VARIABLE THICKNESSES

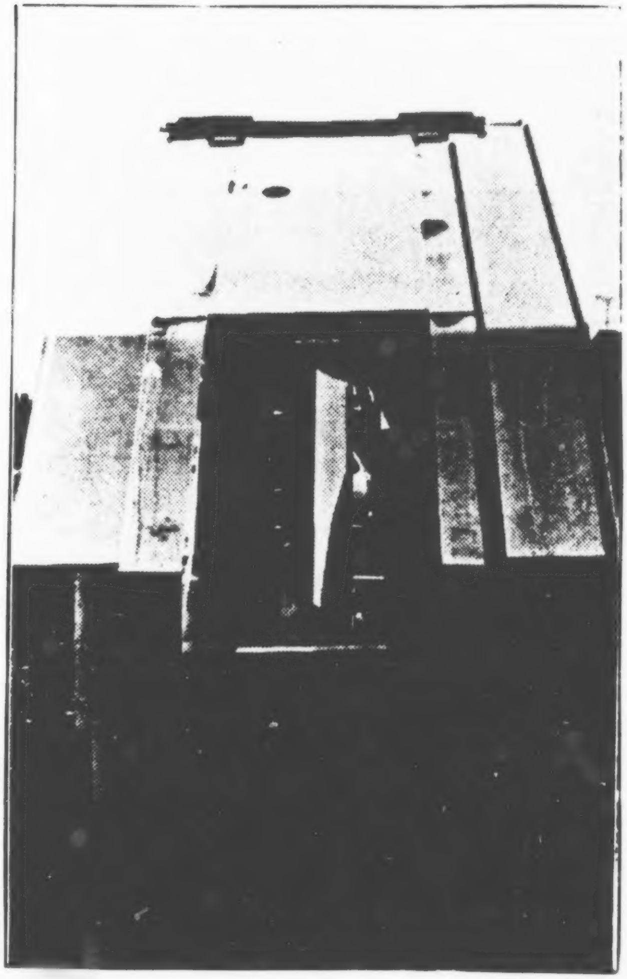
3.2 KEY POINTS

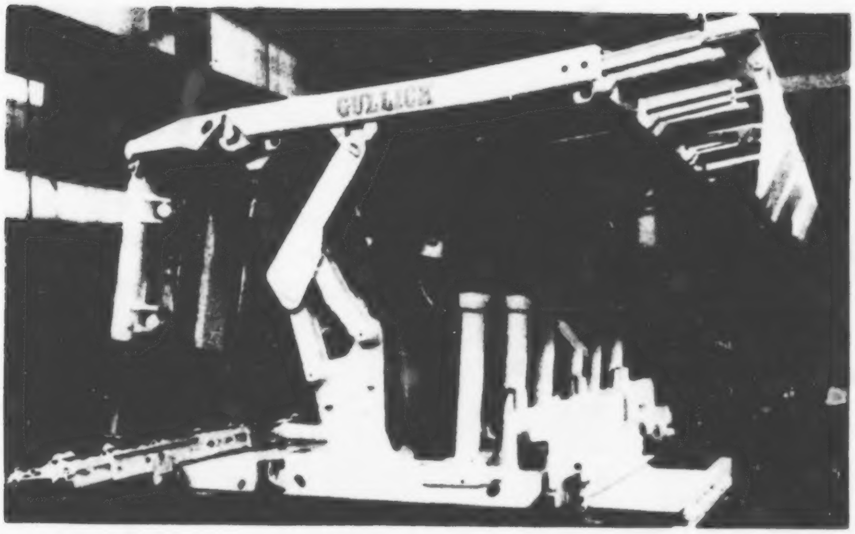
- CONVERGENCE AND FRACTURING
- SPONTANEOUS COMBUSTION
- INTERACTION BETWEEN FACE SIDE AND CAVE DRAWING
- DUST DURING DRAWING

3.3 Cde F, Blanzy, France

LAYOUT	Retreat
SEAM THICKNESS	Highly variable, Max. 60 Ft
MINING HEIGHT	Shearer 9½ Ft, Caving ± 20 Ft
GRADIENT	± 25° Along Face
FACE LENGTH	100 M
PANEL LENGTH	Approximately 250 M
SUPPORTS	Minex and Marrel shields 350/400 tonnes
CONVEYOR	Face side 20" 110/48 Kw Gobside 24" 2 x 110 Kw
POWER LOADER	Sagem SA16, 150 Kw 24" x 54" Drum
PERFORMANCE	± 1000 TPD at 12 - 16 tonnes OMS


15 - 60 ft
9 ft




GULLICK

4.1 THIN - ALONG STRIKE

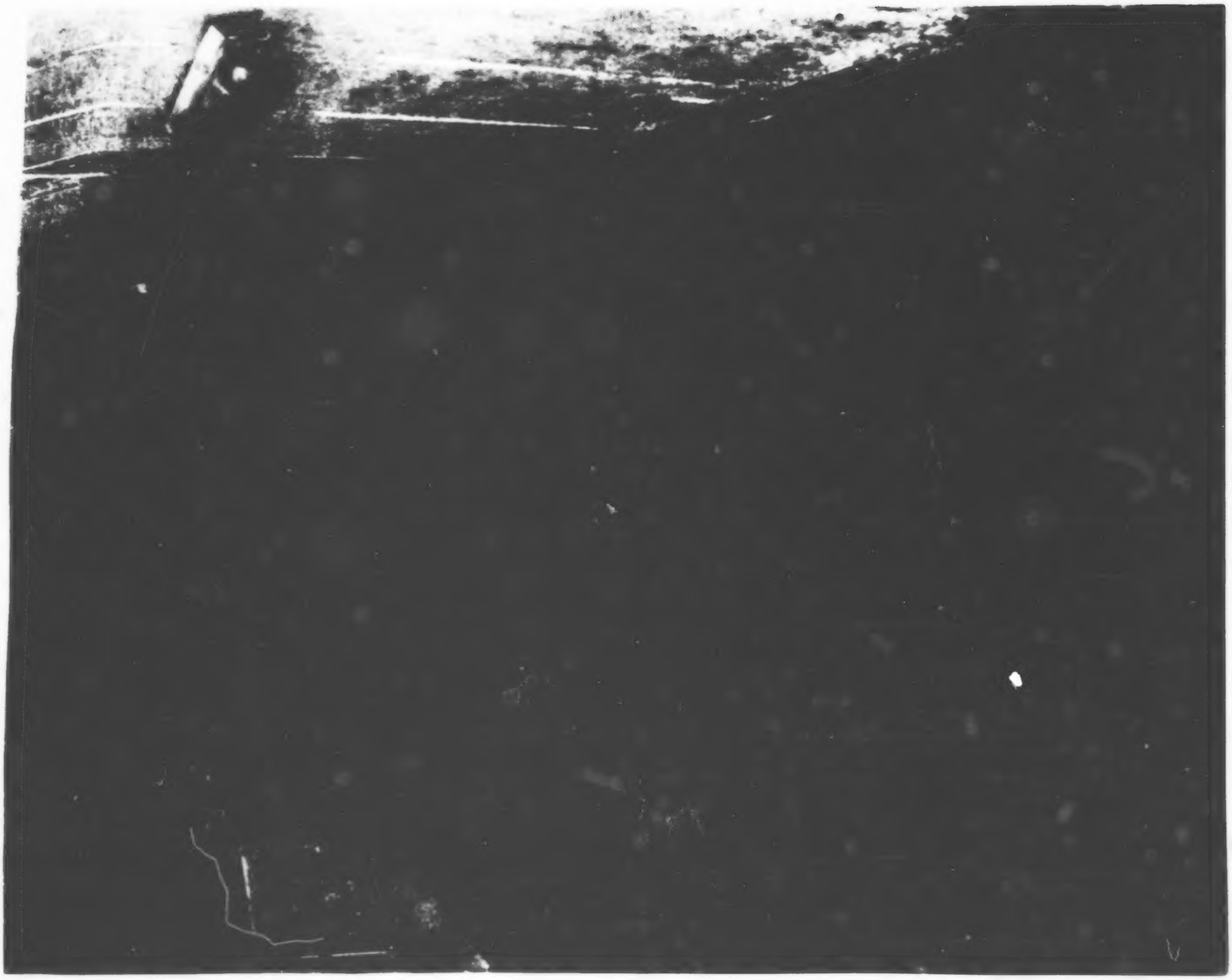
- MEDIUM SEAM TECHNOLOGY SLIMMED DOWN
- THINNER ROOF/FLOOR MEMBERS IN SUPPORTS
- LOW PROFILE OR OFF CONVEYOR POWER LOADER
- NEED HIGH LINEAR CUTTING PERFORMANCE FOR VIABILITY

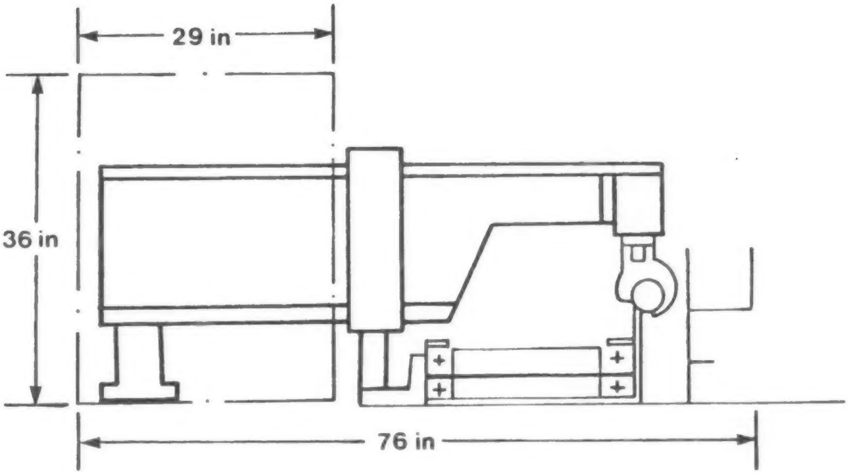
4.2 THIN - ALONG STRIKE

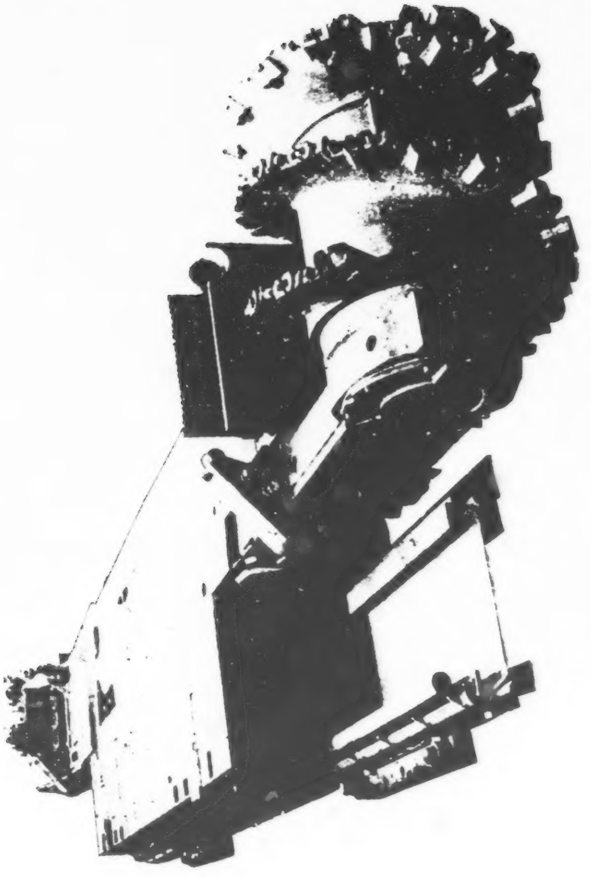
- ROOF CLEARANCE
- COAL CLEARANCE
- STEERING
- SHEARER POWER

4.3 North River Energy Co., Alabama, U.S.A.

LAYOUT	Retreat, 3 entry development
SEAM THICKNESS	± 4 Ft 6 In
MINING HEIGHT	4 Ft 4 In
GRADIENT	Level
FACE LENGTH	600 Ft
PANEL LENGTH	N/A
SUPPORTS	KB 2 leg 350 ton shields
CONVEYOR	KB twin 26 mm inboard chains
POWER LOADING	Eickhoff 150, DERDS, 50" Drum
PERFORMANCE	Record 9196 raw tons/24 Hr




29 in
36 in
76 in

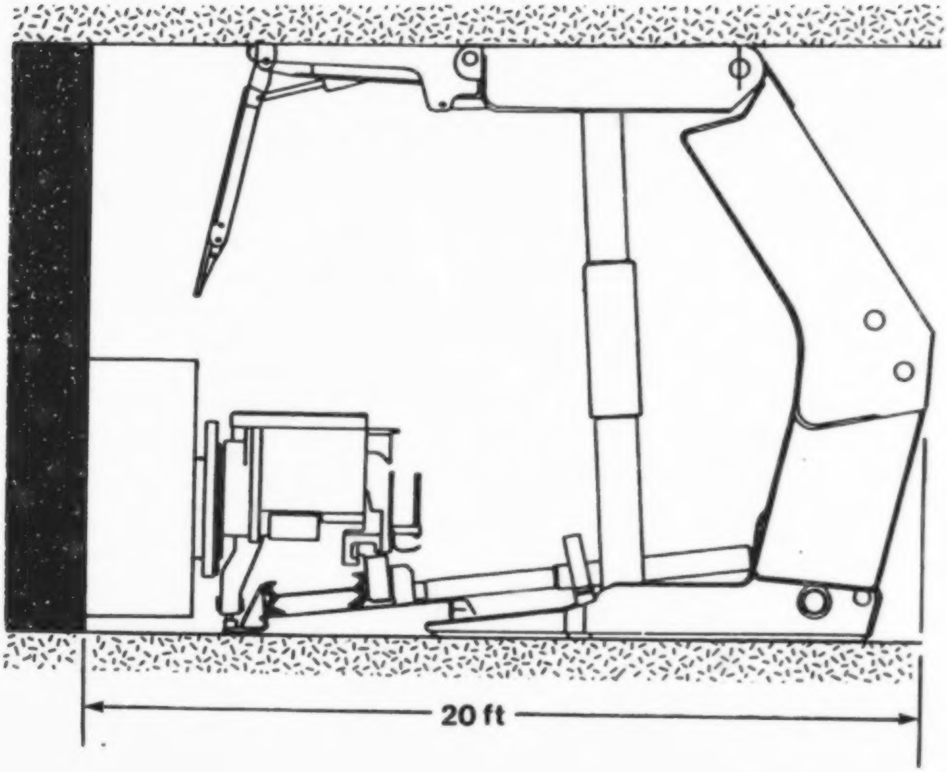


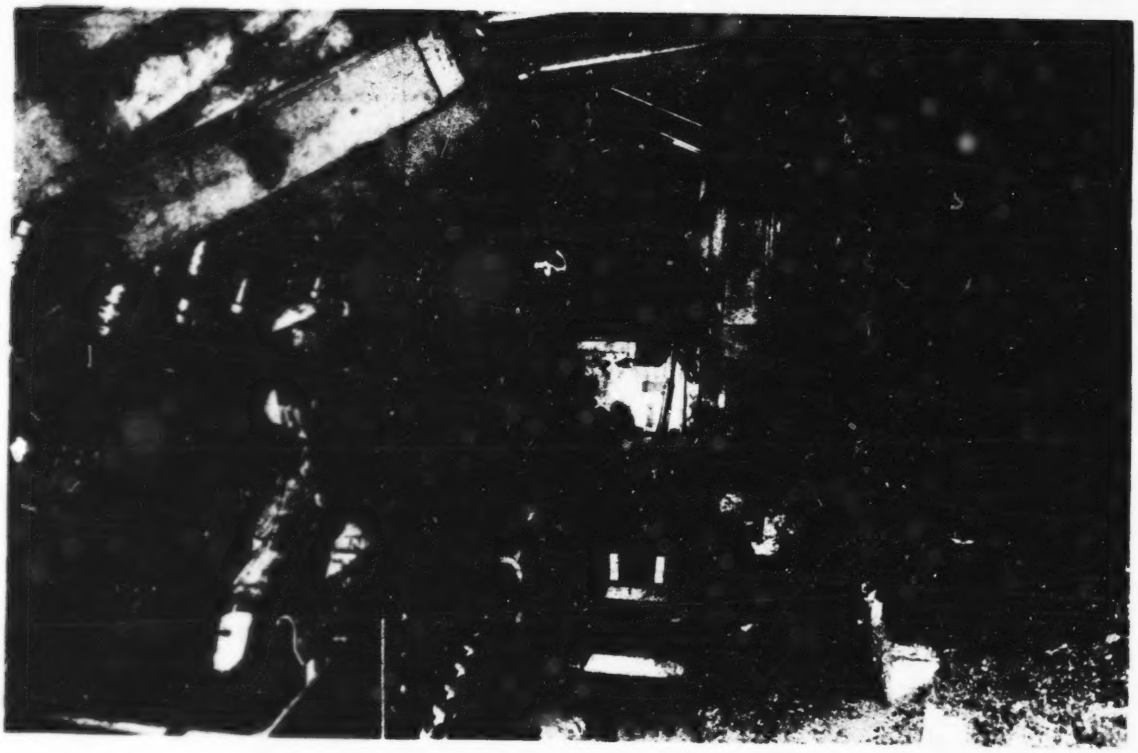
5.1 STEEP - ALONG STRIKE

- MODIFIED FLAT SEAM SHIELD TECHNOLOGY
- INCREASED ATTENTION TO STABILITY
- SPECIAL ATTENTION TO POWER LOADER HAULAGE/CONTROL
- MORE DIFFICULT INSTALLATION AND RECOVERY

5.2 STEEP - ALONG STRIKE

- SUPPORT STABILITY
- CONVEYOR AND SUPPORT CREEP
- TRAVELWAY SAFETY
- CREEP CONTROL
- SHEARER TRACTION/CONTROL


20 ft

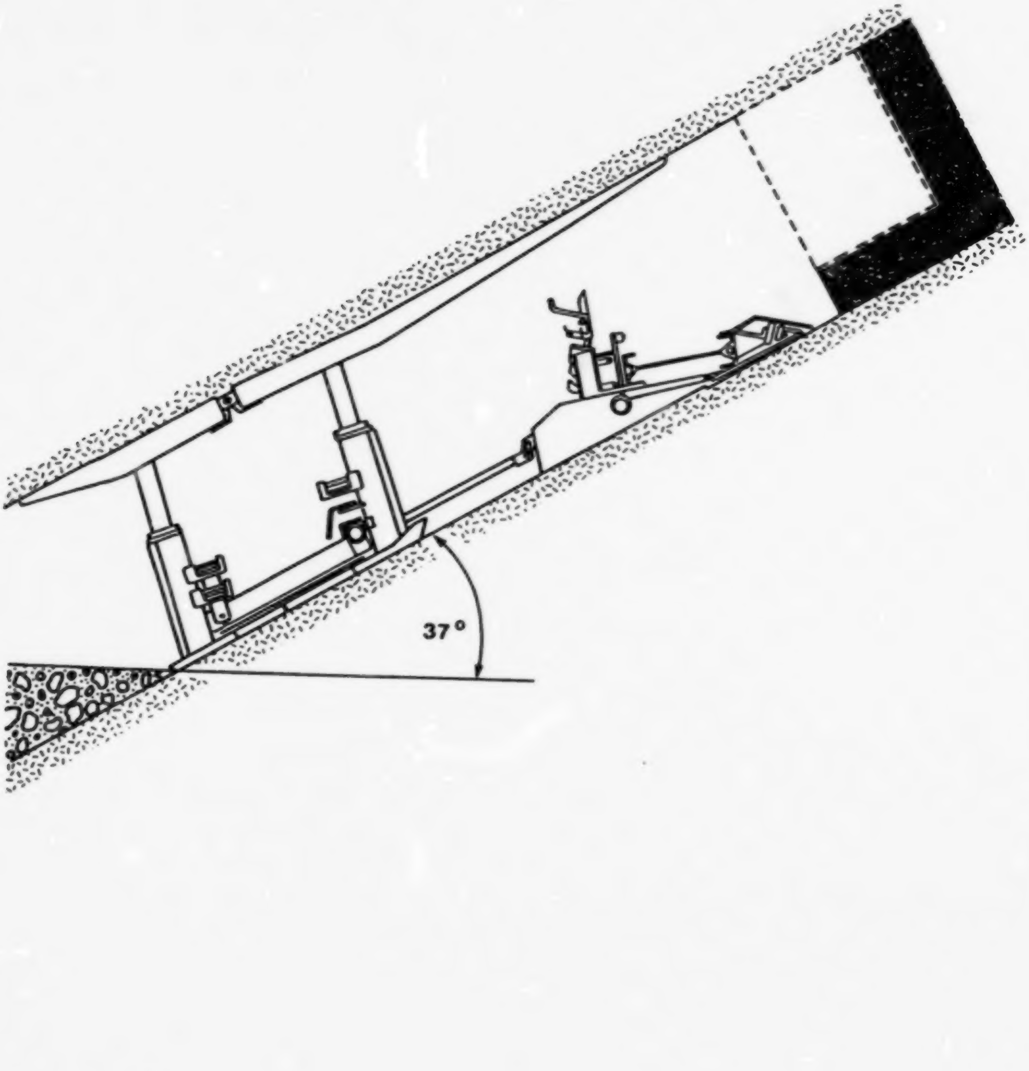


6.2 STEEP - TO THE RISE

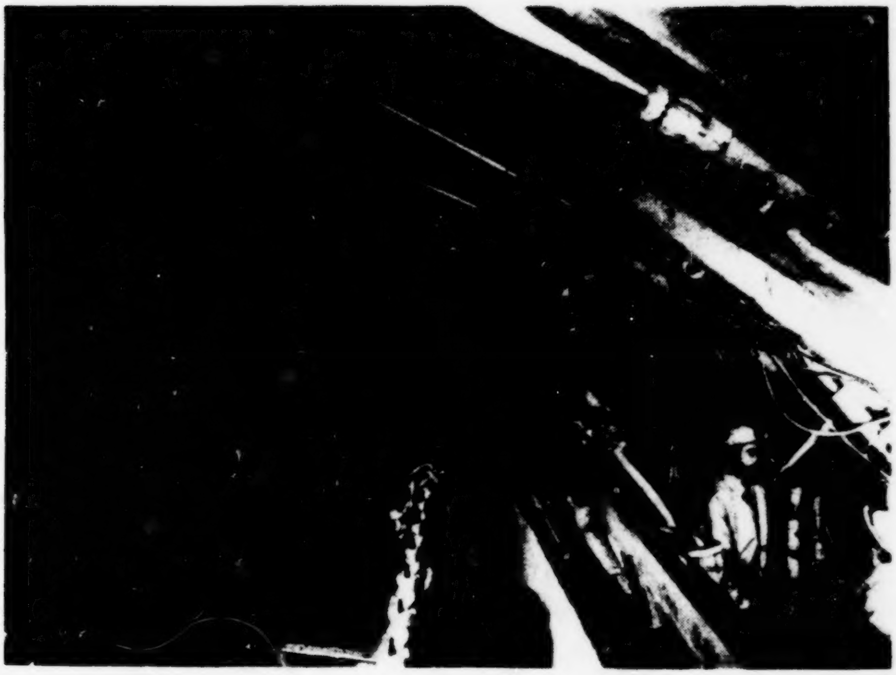
- FACE SPALLING
- SUPPORT BETWEEN BACK OF CHOCKS AND STOWING
- CONTROL OF WIDE ROOF SPAN

6.1 STEEP - TO THE RISE

- WORKING BELOW LIVE COAL FACE
- NEEDS FAVORABLE ROOF CONDITIONS
- GENERALLY REQUIRES STOWING


37°

6.3	Lorraine, France
LAYOUT	Retreat
SEAM THICKNESS	5 - 8 Ft
MINING HEIGHT	5 - 8 Ft
GRADIENT	25° - 45°
FACE LENGTH	± 450 Ft
PANEL LENGTH	1500 Ft
SUPPORTS	4 x 200 chocks, IFS, Special leg stabilization
CONVEYOR	24″, 2 x 160 Kw, on cradle
POWER LOADER	Single drum 140 Kw spec underframe
PERFORMANCE	Est 1000 tonnes/day at 15 tonnes OMS



LONGWALL MINING ON A PITCHING SEAM

James F. Reynolds
General Manager - Snowmass Operations
Western Associated Coal Corporation

ABSTRACT

The principle criteria in the design and operation of a longwall face on a pitching seam are examined. The paper covers the definitions of different pitches and the mine plan of the United States first moderate pitching longwall attempt. The selection of equipment and the training in the use of the equipment in actual production are covered. The production statistics for one year of operation are given.

INTRODUCTION

Snowmass Coal Company, in cooperation with the Department of Energy, introduced the longwall mining method in pitching seams to the United States. This venture is a coal mining research program directed toward the profitable production of coal under difficult mining conditions as found in pitching seams of the Western United States.

Slide 1 There are one and one-half billion tons of recoverable coal under less than 3,000 feet of cover in Colorado in pitching seams. Snowmass Coal Company classifies pitching seams into the following categories for longwall on the strike, in seams ten feet or less thick.

Slide 2 Flat = 0 to 10°: Normal continuous miners and shuttle cars work efficiently.

Slight = 10 to 22°: The maximum pitch that rubber tired equipment will function.

Moderate = 22 to 40°: The angle of repose of mined coal.

Steep = 40 to 60°: The limit of safe use of this roof support.

Vertical = over 60°.

The longwall roof support covered in this report will work in all pitches except vertical. The shearer and conveyor will work in flat through moderate conditions. I believe that longwalling across strike with this equipment in seam pitch over 60° could be accomplished with an inclined face.

Development of the first longwall panel began in 1979 and was completed in 1981. The longwall equipment was installed and mining began on August 11, 1981.

MINE PLANNING AND DEVELOPMENT

Slide 3

The original mine plan took advantage of old works abandoned in the 1960's. The gates were developed on a two-entry system with the entrys rising two degrees to the strike to allow water drainage from the face. The mining method was by Alpine F6A Road Header Continuous Miners with bridge conveyor type coal transport into bottom dump six-ton coal cars hauled on forty two inch guage track by eight-ton battery locomotives. The initial concept was to haul coal from the longwall by battery locomotive. Lack of discipline is shown in the irregular direction of the gate entrys. Local rolls in the coal seams severely limited the capacity of battery locomotives.

The current mining law prohibits the use of an intake escape way for belts or trolley locomotives. A two-entry system is the simplest method of panel development in a pitching seam. A continuous miner cannot be trammed from one entry to another because of steep X cuts. Thus, the development requires a continuous miner in each entry. The configuration of the old mine works resulted in a first panel longwall block of three hundred fifty five feet by five thousand four hundred feet.

In panel development the use of battery locomotives became evermore costly. When the panels were completed and the set-up room finished, the lower gate entry was changed to a belt entry and the use of battery locomotives for coal hauling was abandoned. A new slope was driven and the mine supply system was converted from rail battery locomotive to rubber tire diesel supply. The latest generation of Roadheader and standard high powered shuttle car-to-belt system is now used for development.

Slide 4

SELECTION OF LONGWALL EQUIPMENT

Longwall mining across the strike on pitching seams is currently practiced in many nations. Equipment similar to that used by flat seam longwalls is available for pitching seam use in Great Britian and Germany.

Slide 5

The important considerations for the selection of the face equipment were: A twin outboard armored face conveyor was selected to give maximum retention of coal on the conveyor due to flight rigidity and to prevent coal from sliding down the face and jamming the lower belt gate; Dowty 22 mm twin-outboard face conveyor for a three hundred fifty foot face with a single 150 HP drive at the gate was selected. Wiser heads insisted on twin 150 HP drives (one at each gate) and this system is now used. The ramp plate on the face side of the conveyor has a square edge. The hard floor will not allow the ramp plate to dig in. The square edge prevents the conveyor from climbing on loose coal. One meter high spill plates are used to reduce injuries from flying coal, and rock sliding down the pitch.

Slide 6

Most countries in Europe use chain haul shearers with a safety winch assist for moderate pitching seam operations. The safety winch would be used to hold the weight of the machine and allow the chain haul power to be used for coal cutting force. On a thirty degree pitch the shearer machine has an equivalent weight of thirty thousand pounds. A mechanical driven chain haul shearer has a haul power of about eighty thousand pounds.

Snowmass chose an Anderson Maver 500 HP chainless haul shearer equipped with three each hydraulic motor driven roll rack drive units. Each unit has the haul power of forty thousand pounds for a total power on the machine of one hundred twenty thousand pounds available to haulage. Each haul drive unit is equipped with dual disc brakes. The machine has no need for a winch because the shearer has fifty percent more haul power than most shearers and twice the additional power needed to overcome the pitch. It's speed is slower than a normal shearer because of the oil diverted to additional tram motors. The maximum cutting speed is now twenty seven feet per minute. In an eight-foot coal seam with a twenty four inch effective web, this is equivalent to 1,057 tons per hour at maximum speed. Radio control with a single operator was added for use, if needed, for operator safety.

The drum design is sixty inches in diameter equipped with fifty four front flush picks with a design web of thirty inches.

Because of unknowns in rib sloughage, safety and dust problems, the machine was equipped with a single operator radio control. We have had no problem with local rolls in the coal seam on the chainless haul. This machine became the worlds first radio controlled chainless haul shearer operating on a thirty degree pitch.

The shearer is equipped with a lump breaker on the up pitch and no safety winch was used. We manufactured a safety sprag on the down hill side which will stop the shearer against the conveyor in case of a brake failure. In addition, the conveyor is advanced behind the shearer to keep runaway into solid coal.

Slide 7

The double hydraulic powered roll rack units are compact, powerful and easy to maintain. The roll rack bars are two inches wide and doweled and bolted into the conveyor pan. Each rack bar is shorter than the conveyor pan. This allows a spacer bar to be used across the joint for smoother shearer travel. As long as the trapping shoes are well maintained, the roll rack drive and rack bars are virtually maintenance free.

ROOF SUPPORT

Slide 8

Snowmass selected the most modern two-leg shield roof support system for pitching seams made in the world. The shields are Hemscheidt Troika system design, three hundred fifty ton two-leg support, made for seam height 1.5 meters to 3.0 meters. The shields are equipped with a thirty inch forepole canopy and face spill plates. The roof support operates independent of the face conveyor in groups of three. The word "Troika" is Russian for 'three horse sleigh hitch' in which the outer two horses must follow the lead of the center horse. Thus, in each three shield set, the center shield is rigidly attached to a bar and the center shield is advanced by DA rams of the two outer shields.

Slides 9,10,11 A steering ram allows the center shield to be moved uphill or downhill. The two outer shields then advance to the placement of the bar on the center shield. Side ram plates on each shield allow vertical positioning.

The conveyor is advanced by a dual acting ram attached to the topmost shield in the troika. The conveyor is not attached to this ram and cannot be retracted. Anti-creep rams are positioned in every other troika bar. These rams are attached to the conveyor by a 15' x 18mm chain. Thus, the whole face, roof support and conveyor, can be moved up the hill or down the hill as much as three inches on each web cut. Uphill motion of the conveyor is controlled by pressurizing all the anti-creep rams. Downhill motion is affected by relaxing up to half of the anti-creep rams. Slide 12

TRAINING

Perhaps the most effective part of Snowmass' longwall operation was the training. To start, a one hundred fifty foot long section of a complete longwall panel was set up on the surface. From this set-up we assembled the longwall equipment and made the changes necessary to make the various equipment compatible.

Slide 13

To set the face, all of the underground maintenance personnel were rotated through the set-up procedure to learn the longwall assembly and electrical, hydraulic and mechanical functions. Once this set-up face was functioning, most of the underground mining personnel were given two days familiarization training. When the familiarization training was finished, the three shift crew jobs were posted and awarded. Successful applicants for the longwall positions were then given two weeks additional training on the longwall operation on the surface. These crews then dismantled the surface demonstration, transported and installed the longwall at the mine set-up raise. The equipment was installed on the thirty degree pitch from the bottom to the top using a fifty ton hydraulic winch and six Neuhaus fifteen ton air operated chain hoists. The set-up time, from surface to underground operation, was five weeks.

Slide 14

Training in the mine began with a single shift operation using two full crews. Hemscheidt service people directed the roof support operation; Anderson Mavor people directed the shearer training, and Dowty service people directed conveyor advance and stage loader advance training. Within two weeks the longwall was up to full speed on two shifts per day.

In addition to on-the-job training, three of the foremen were sent to the First Leopold Mine in Germany for six weeks hands-on training on their pitching seam face. One maintenance foreman was sent to Scotland for hydraulic and electrical training on the AM500 shearer.

The experience has been that set up of a longwall to produce three shifts a day without scheduled maintenance is condusive to rapid deterioration of the longwall equipment. Snowmass is set up to mine two shifts, then down one for scheduled maintenance. Hydraulic maintenance is scheduled on one operating shift every day. Shearer maintenance on trapping shoes and disc brakes is accomplished every three weeks on schedule.

OPERATIONS

The day shift face crew consists of a foreman, two shearer operators, one conveyor man, two shield movers, one conveyor control operator and two maintenance men. One day shift maintenance man is specialized in the face hydraulic system. Second shift manning is the same as first shift except that only one maintenance man is used. The supply and maintenance are performed on third shift by a maintenance foreman and four service personnel. The third shift maintenance crew is trained to cut coal.

The shearer cuts a 0.6 meter (24 inches) web of coal. Bi-directional cutting is applied to avoid walking the thirty degree slope with no coal production. Once the snake or sump is made, the face conveyor is advanced behind the shearer. This minimizes the distance of possible run away on the shearer. When mining up pitch the shearer is tramming at twelve feet per minute which is a mining rate of five hundred tons per hour. This is sixty percent of the shearer capacity in coal. Mining down the hill

Slide 15

requires twenty percent of shearer capacity at twelve feet per minute. The mining rate down pitch is restricted to lump size ahead of the shearer. The maximum tram speed on this shearer is twenty seven feet per minute with a mining rate of 1,057 tons per hour.

The longwall face is operated on full pitch at ninety degrees to the gate entries. Troika roof supports are advanced every other troika with the conveyor restraining device advanced first. There are conveyor restraining or anti-creep devices in every other troika bar. These devices have to be relaxed to advance the troika bar and prevent damage to the anti-creep rams and chains. Usually one shield mover and the conveyor mover work together to move and align the conveyor and those troikas which hold the conveyor. The other shield mover follows and moves the remaining troikas. The longwall face is run tight - not one web back. Crews walk the face on top of the troika bar which has ladder rungs welded to the bars. Walking on the rock floor on full pitch is very difficult.

Spacing of the troika bars is set by a wire rope welded to both ends of each bar. Face distance can be varied by expanding or contracting the troika system and simply having the wire rope ends as a guage. Thus, a three hundred fifty foot face with twenty one troika sets can be expanded to a three hundred eighty foot face or contracted to a three hundred thirty foot face. The face conveyor can be walked up pitch by pressurizing all eleven anti-creep rams during the regular mining cycle of the conveyor or it can be walked down pitch by relaxing four or five of the anti-creep rams. The force of the shearer in the mining cycle causes the conveyor to go with the change in hydraulic tension on the conveyor. There are no roof support to conveyor connections to worry about.

The gate end troika are operated one web back to allow room for the conveyor drives. Support in the tailgate is provided by fiber reinforced concrete cribs and hand operated single props.

All of the electrical controls except the transformer are mounted on top of the stage loader. The stage loader can advance over the belt tailpiece a distance of thirty feet before the tailpiece need be moved. A direct drive lump breaker is mounted in the stage loader. The total length of the stage loader is one hundred four feet. Advancing the stage loader is accomplished by a single shield in the gate entry. Gate entry support is accomplished with water props.

Abutment pressure and gate entry pillar pressure are measured by instrumentation ahead of the longwall face.

SAFETY

Falls of roof are exceptionally dangerous on pitching seams because the rock falls down and then slides down. Guards must be built on the stage loader to prevent flying rocks that slide down the face conveyor ramps from striking persons in the belt gate.

Injuries to the knee occur at an alarming rate to workers and visitors not conditioned to a pitching seam operation. Injuries to the lower back and tail bone are above average due to slips and falls on the pitch. Bi-directional cutting gives the maximum productivity to face walking rates. This reduces the injuries to the knee and from falls due to fatigue.

Slide 16 Snowmass uses fiber reinforced concrete cribs in the gate entrys. No shields are used in the tailgate. We have not experienced any gate entry falls. The illustrated roof control plan works very well.

Our average injury rate is 14.3 which is 150 percent of the national average.

PRODUCTION

Slide 17 Seventy percent of our one hundred forty man underground work force are trained on the longwall. All of the face crew are paid a single high rate. These crews are able to interchange on jobs.

Snowmass does not shut down for vacation. All of our personnel are allowed to schedule vacation at their will. Because of the training, absenteeism has minimal effect on face production.

The number of shearer cuts per day is set by plant capacity at this time. We expect to average five cuts per shift, which is 1,180 tons per shift. Our peak loading rate has been 2,380 tons per shift.

The attached table shows statistical averages for the latest three month period.

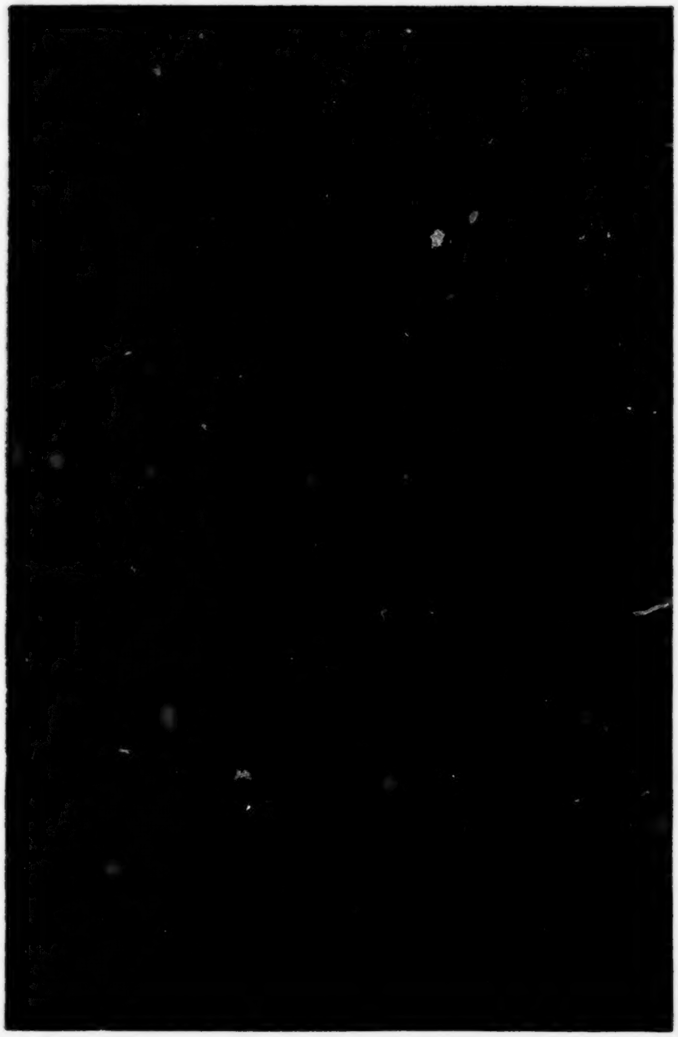
CONCLUSION

Snowmass performance shows that the capacity of a longwall operating on moderate pitch, up to forty five degrees, should be the same as a flat seam longwall. With the equipment now available, pitching seam longwall is not only feasible but cost competitive. The actual roof support method of troika concept has excellent maneuverability, good support, and is low maintenance. The shearer has proven power to operate on moderate pitching seams.

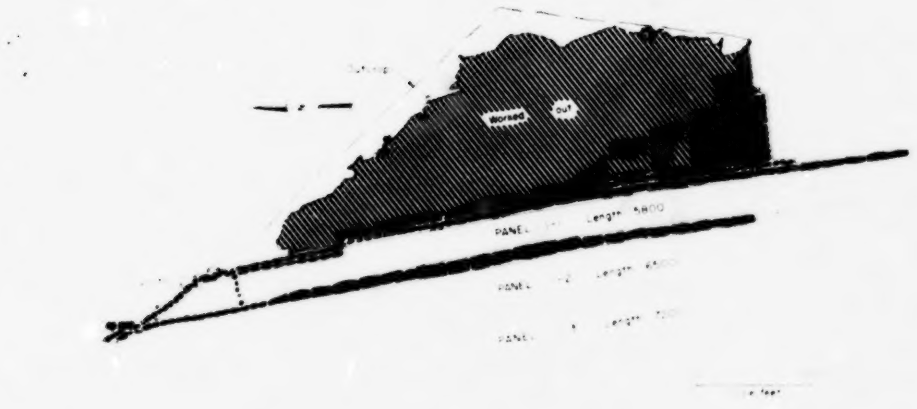
LONGWALL MINING IN WESTERN CANADA
TWO DAY SEMINAR 14/15 NOV 1983

NOTE PAPER

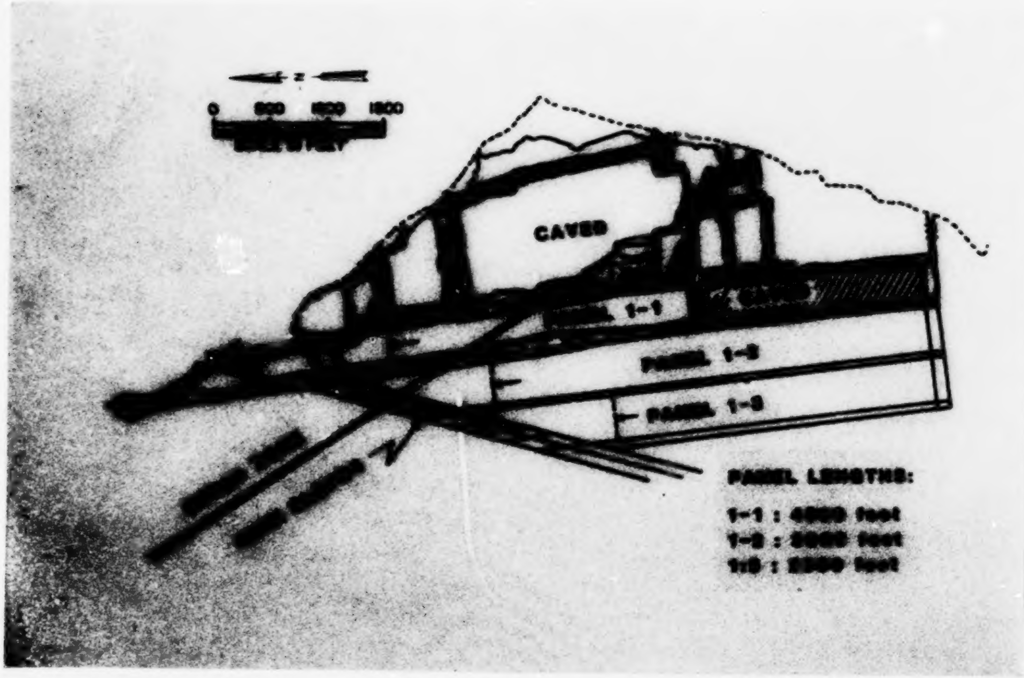
SLIDE 1

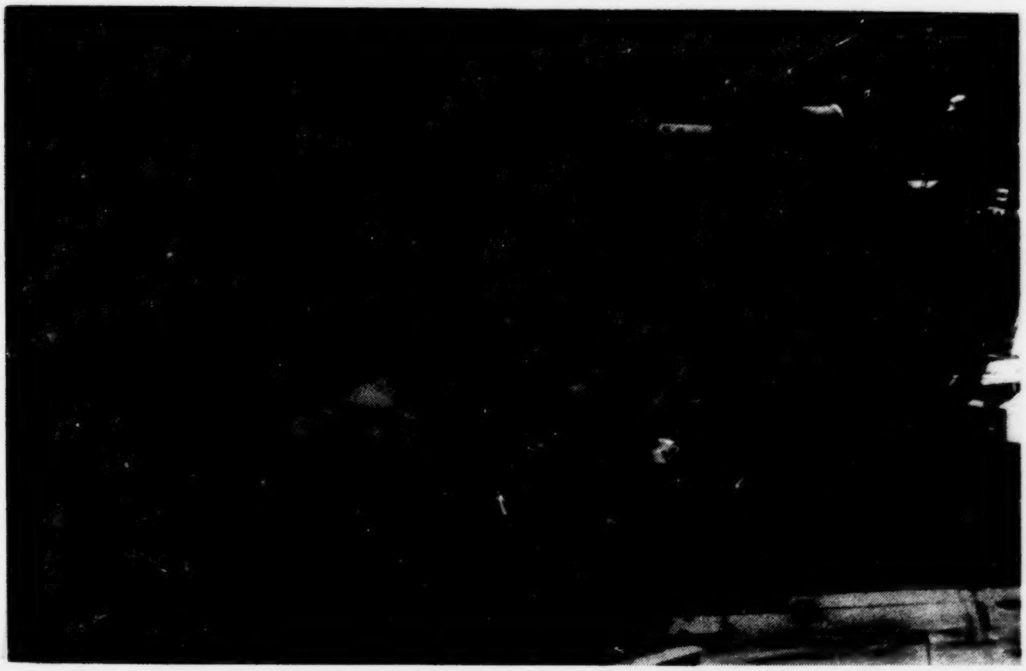


SLIDE 2


Outcrop
N
Worked
out
PANEL 1-1 Length 5800
PANEL 1-2 Length 6500
PANEL 1-3 Length 7000
in feet

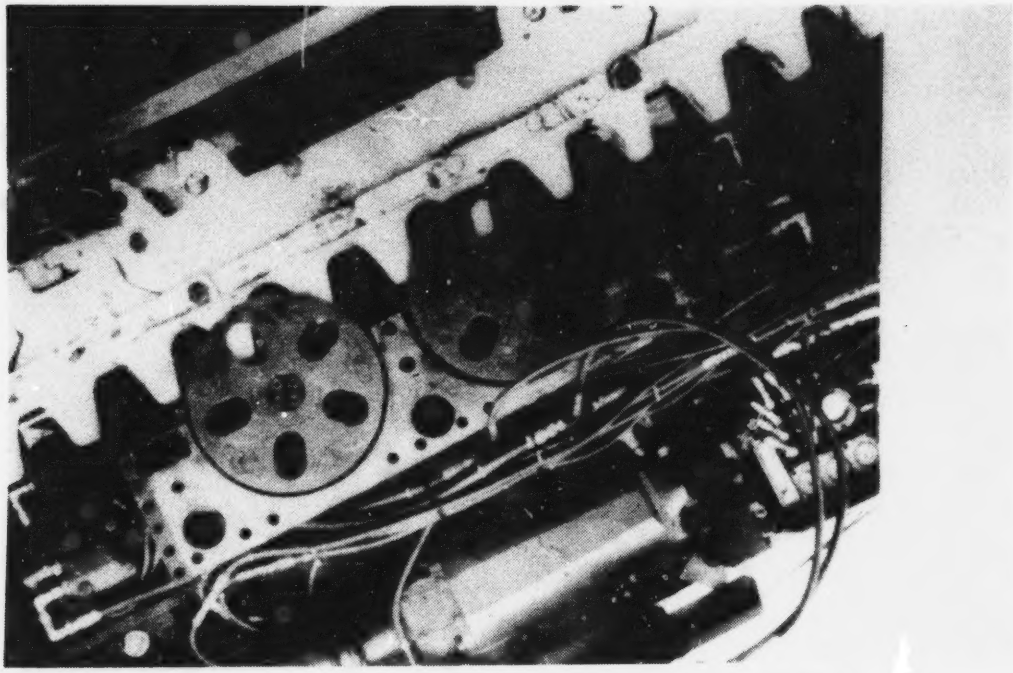
PROPOSED PANELS—STEEP SEAM LONGWALL DEMONSTRATION


N
0 600 1200 1800
CAVED
PANEL 1-1
PANEL 1-2
PANEL 1-3
PANEL LENGTHS:
1-1 : 4800 feet
1-2 : 3600 feet
1-3 : 2300 feet

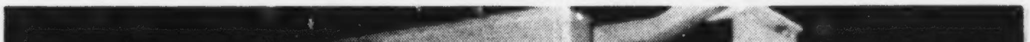


SLIDE 5

SLIDE 6

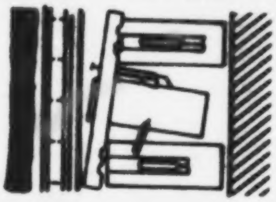


SLIDE 7



SLIDE 8

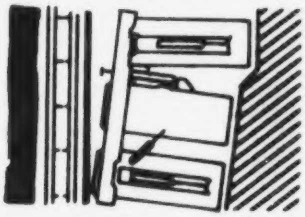
TROIKA STEERING



STEP 1

D.A. Ram on Lower Support is Extended Advancing Middle Shield and Turning It Upslope

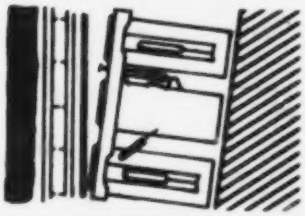
TROIKA STEERING



STEP 2

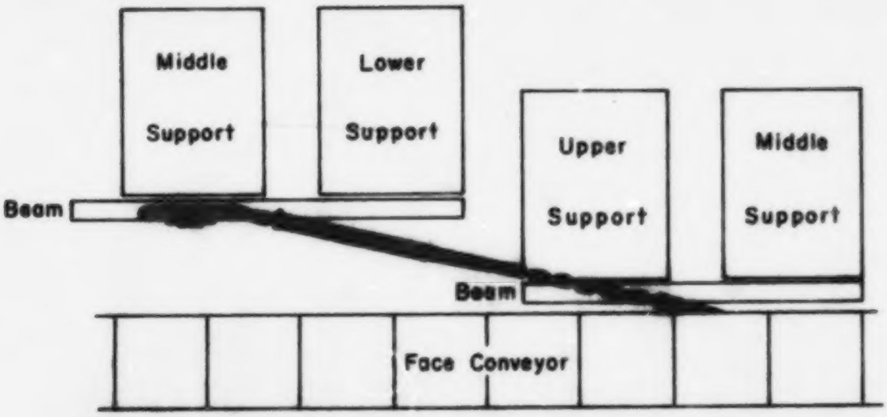
Lower Support Advanced and Automatically Aligned Parallel to Middle Shield

TROIKA STEERING

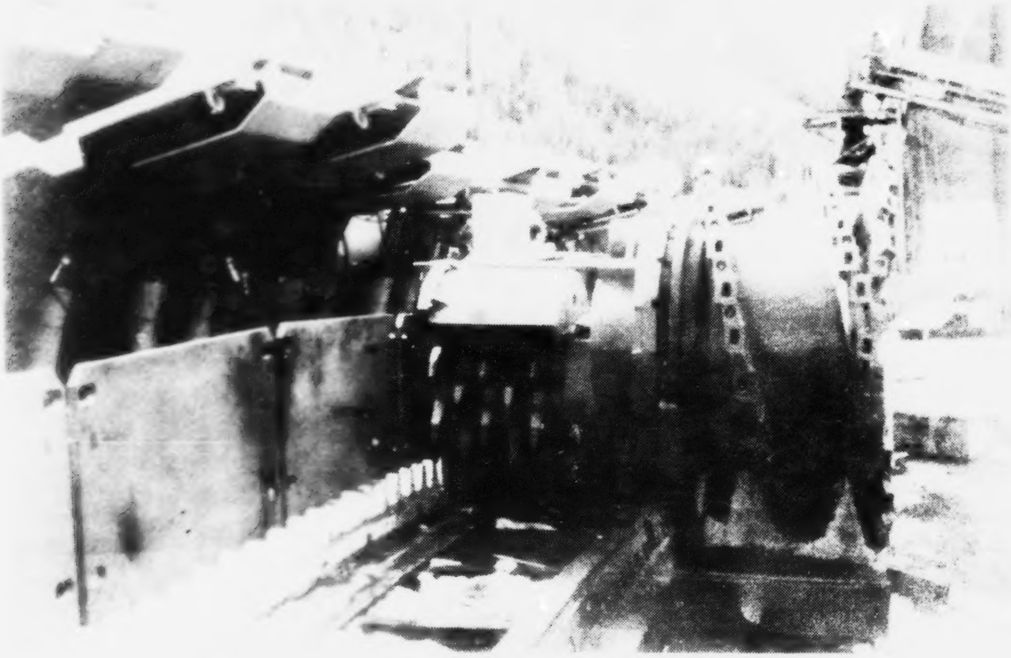


STEP 3

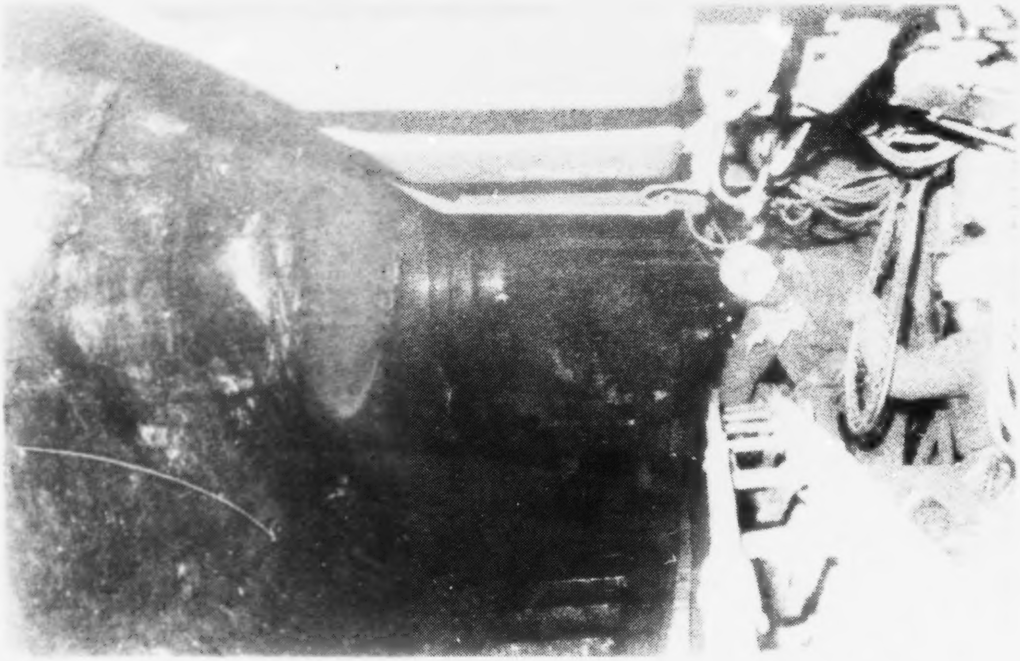
Jpper Support is Advanced and Realigned Slightl


Middle Support
Lower Support
Upper Support
Middle Support
Beam
Beam
Face Conveyor

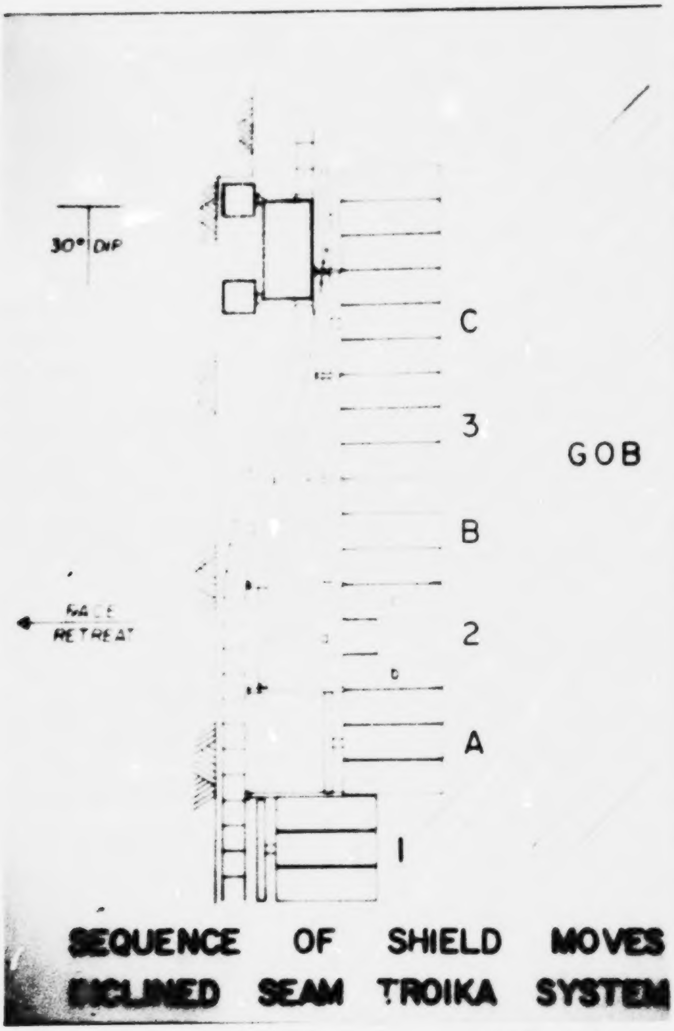
FACE CONVEYOR ANCHORS



SLIDE [illegible]



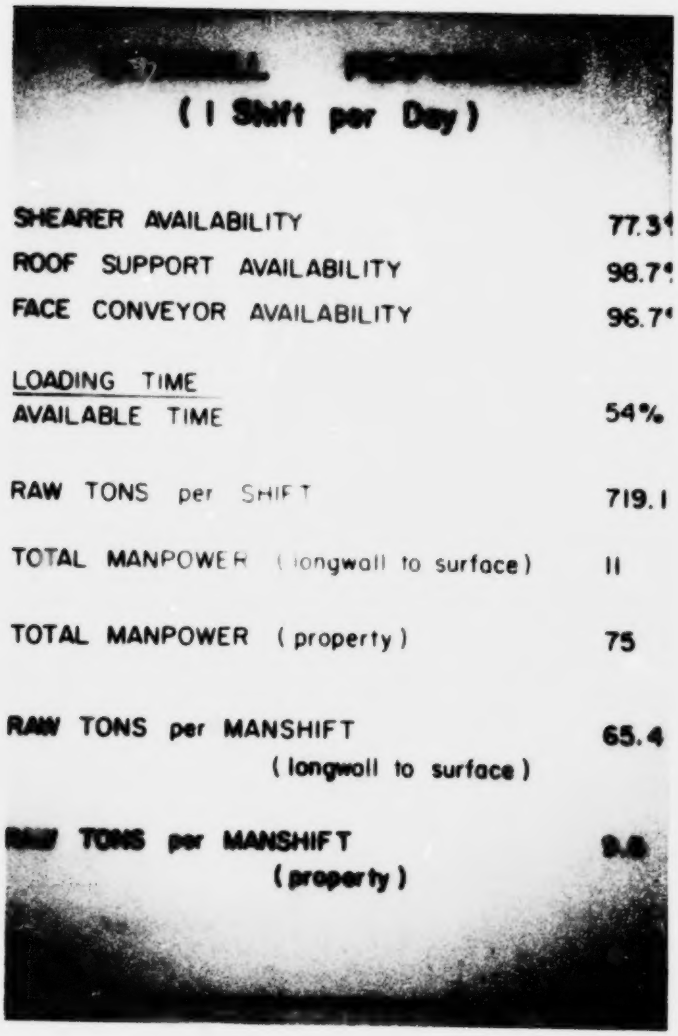
SLIDE [illegible]


30° DIP
FACE RETREAT
C
3
B
2
A
1
GOB

SEQUENCE OF SHIELD MOVES
INCLINED SEAM TROIKA SYSTEM

SLIDE 15

SLIDE 16



[illegible] [illegible]
(I Shift per Day)

SHEARER AVAILABILITY	77.3%
ROOF SUPPORT AVAILABILITY	98.7%
FACE CONVEYOR AVAILABILITY	96.7%
$\frac{\text{LOADING TIME}}{\text{AVAILABLE TIME}}$	54%
RAW TONS per SHIFT	719.1
TOTAL MANPOWER (longwall to surface)	11
TOTAL MANPOWER (property)	75
RAW TONS per MANSHIFT (longwall to surface)	65.4
RAW TONS per MANSHIFT (property)	9.6

SLIDE 17

POOR

QUALITY

ORIGINAL